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CONTENTS.

EDITORIAL:

Electrochemical Processes for Equalizing Central Station Load
Curves 347

Remember the Reader 348

A Logical Guess to Coal Mine Explosions 349

The Psychological Moment to Get Ready for Prosperity 349

THE IRON AND STEEL MARKET 350

Iron Ore Production of the United States 350

Manganese Ores 351

Ferroboron Prize Competition 351

CORRESPONDENCE:

Radioactivity. By G. L. Cabot 352

Worlds in the Making. By Carl Hering 352

Treatment of Iron and Steel in Electric Furnace. By Francis

A. J. Fitzgerald 353

Steel Foundry Practice. By R. A. Bull, R. H. Wolff and W.

M. Carr 354

Electrolytic Refining of Gold, Silver and Copper at the United States

Mint, San Francisco, Cal. By Robt. L. Whithead 355

New Thermite Reactions. By Hans Goldschmidt 360

Cold-Junction Temperature Corrections of the Pt. Pt Rh. and Pt. Pt

Ir Thermo-Electric Pyrometer. By Cornelius Offerhaus and Ernst

H. Fischer 362

Electrodeposition of Nickel. By Edward F. Kern and Francis G.

Fabian 365

On Methods of Obtaining Cooling Curves. By G. K. Burgess 366

Grinding. By Oskar Nagel 371

Notes on Electrochemistry and Metallurgy in Great Britain 375

SYNOPSIS OF PERIODICAL LITERATURE 377

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS 379

RECENT METALLURGICAL PATENTS 381

National Waste. By Oskar Nagel 382

Mercury Ammeter for Large Currents 383

Disinfecting Liquid 384

What a Manufacturer Should Know About Coal 384

Refined Copper 386

Tilting Crucible Furnace 386

NOTES 387

DIGEST OF ELECTROCHEMICAL U. S. PATENTS (Electric Furnaces) 389

NEW BOOKS 390

BOOK REVIEWS. Clarke's Data of Geochemistry 390

Nicolardot's Industrie des Metaux Secondaires et Des Terres

Rares 390

Stanfield's Electric Furnace 390

Electrochemical Processes for Equalizing the Central Station Load.

Niagara Falls and the French Alps are the two largest centers of electrochemical industries. Yet it would be wrong to conclude that cheap water power is necessary for the success of electrochemical work. The majority of the large electrolytic copper refineries of this country have been established near New York City and are operated by steam power. Other considerations, like freight and labor conditions, are important besides power. But it is true that power is one of the most important items on the cost sheet of any electrochemical process. It is natural that progressive central stations in their endeavor to find new customers, especially at times of weak load, are turning their attention to electrochemical industries. The easiest method of storing electrical energy is in form of chemical energy. The lead storage battery is the classical example. But every electrochemical product may be considered as a substance in which electrical energy is stored in form of chemical energy. To make electrochemical products is equivalent to the storage of energy. What the electrochemist needs is cheap power. Both sides must necessarily make concessions. The central station must be willing to make a low rate. The electrochemist must be willing to take the power only at certain hours of the day; that is, he must work intermittently. Is it possible for both sides to make such concessions?

* * *

If a central station can fill up the serious valleys of its load curve by electrochemical processes, its fixed charges and pay roll are not affected; it is essentially the fuel cost that increases. A low rate should not be out of place under such conditions. The electrochemist, like everybody else, desires to work continuously at full capacity. But there are electrochemical processes which can be worked with profit intermittently and there are others which must be worked in that manner (carborundum, graphite). Electrolytic processes are not easily adapted to such conditions. It is to electric-furnace processes that the central-station men should turn their attention. The subject has been ably discussed by C. J. Russell in a paper before the Association of the Edison Illuminating Companies in 1906 and in three American Electrochemical Society papers of E. A. Sperry and John Meyer (Transactions, vol. 9, 11, 13). A good commercial beginning has already been made by the Philadelphia Edison Company. Now the Brooklyn Edison Company is entering the same field, as is indicated by a recent conference to which officials of the Brooklyn Company had invited a number of Philadelphia Edison men and several electrochemists. It is still true, however, that both sides—central-station men and electrochemists—have not yet come to a sufficient understanding of their mutual needs. This can come only through discussion. We will gladly place our correspondence columns at the disposal of both sides, in the firm belief that when a

clear understanding is reached more tangible results will follow. Central-station men should make up their mind how low they can make their rate and for how many hours they can guarantee to supply power per day continuously. On the other hand, electrochemists and electrometallurgists should consider whether the evident advantages of a reasonably low power rate in a large city would not outweigh the disadvantages of intermittent working. It is clear that each case must be considered separately and must be decided on its own merits. For many electric-furnace processes, within a certain size, it should pay to look carefully into the possibilities of such an arrangement.

Remember the Reader.

Mr. T. A. Rickard, the distinguished and genial mining engineer and editor of the *Mining and Scientific Press*, has recently published a small book entitled "A Guide to Technical Writing." The numerous friends of the author or of his multifarious papers and books know that he has something to say on the proper use of the English language. It is hardly necessary for us to add that the author states his case well and in a pertinent and straightforward manner. We sincerely hope that his little book will provoke greater attention to the fundamentals of good technical writing and will prove a useful help to writers on mining, geological and metallurgical subjects. For it is to this class of technical writers that the special illustrations of the rules of the author will particularly appeal. We have emphasized before in these columns the importance to engineers not only of correct thinking, but of concise and clear expression of their thoughts in reports as well as in articles and papers. For the time will come when the powers of writing and speaking well and to the point will turn the balance betwixt mediocrity and eminence. If someone thinks he has something to say he should say it well, that means, in such a way that the reader will easily and concisely catch the meaning. "Remember the reader" is a leitmotiv that appears again and again and always forcefully in Mr. Rickard's essay. It is such a good general rule that it suggests a few words on some points not touched by Mr. Rickard.

The first point we wish to make relates to references to prior work. It seems that modern technical writers grow more and more careless in giving references, if they do not omit all references to prior work of others altogether. Two examples may illustrate this. A paper presented a few weeks ago before the Faraday Society in London on recent developments of the induction furnace, contains interesting observations on the "pinch effect." The lack of any reference, however, to prior investigations of this phenomenon seems a mistake. The average reader cannot be expected to know the work of C. Hering, P. Bary and E. F. Northrup. He will, therefore, not recognize that the results obtained by the present author with the induction furnace are an interesting confirmation of former researches. The average reader may also be misled to think that the pinch phenomenon is in some way peculiar to the induction furnace, while as a matter of fact under suitable conditions it will manifest itself in any liquid or gaseous electrical conductor. The phenomenon as described by the author is an interesting isolated fact, nothing more. If

he had added the references (a few lines would have been sufficient), the reader would have been able to see the value of these observations in their proper light and in their proper connection with other facts. To omit references to prior work is universally unfair. It is not fair to those who did the former work. It is not fair to the present author (because such an omission, while being simply the result of carelessness or laziness, may easily be misconstrued as being intentional). But above all, it is not fair to the reader. An author who has something to say on a subject may be expected to have all the references at his fingers' ends. To give them would be for him the work of a few minutes, while for somebody not acquainted with the subject it may mean a search of days or weeks.

* * *

In a recent article published in an American journal reference was made to a special steel patented by a well-known engineer "a few years ago." The reference seemed fairly good. It seemed an easy matter to find the patent. Our experience was as follows: In view of the nature of the steel it was expected that the patent had been granted after 1900. In looking through the yearly indexes of the Patent Office from 1900 to 1906 it was quickly found that the patent had not been granted during these years. From the reference, as given, it then did not seem impossible that the patent might have been applied for "a few years ago," but granted only recently. The patent office has not yet published the yearly index for 1907 and has only announced that the bimonthly indexes for 1907 will not be published at all (another of those truly remarkable changes of this institution). It thus became necessary to look through all the weekly gazettes, with the result that the patent was not found. It was finally discovered among the 1896 patents, but it was necessary to read the specifications of all the patents granted to the prolific inventor in question, since the title of the patent did not indicate anything of a special steel. This search took just five hours. Surely no author has the right to waste other people's time.

* * *

The other point on which we wish to say a few words is the use of formulas in technical literature. There are still a few "practical men" who confess openly that they will not read an article if it contains formulas or mathematics. There are still some more who think the same, but no longer say it. Nevertheless, the ridiculous and thoroughly unfounded dislike of formulas, which was formerly common among practical men, is rapidly disappearing. Metallurgy has changed with surprising rapidity from empiricism to applied science. A clerk in a business office who does not understand stenography is left in modern business life. A metallurgist who does not understand to interpret a chemical formula will also be left. It is necessary to recognize fully the wealth of information that can be obtained from a simple formula. It gives the relative weights of the substances involved in a process; if there are gases involved, the formula gives their volume; with the aid of thermochemical tables it gives the energy balance sheet of the process; if the process be electrolytic, the formula gives the relation between ampere-hours and weights, and so on. All this information is obtained from one and the same equation. Chemical formulas represent the most concise short-hand method imaginable. Moreover, they are understood

the world over. They are the natural esperanto of chemists and metallurgists. In the interest of the reader, chemical equations should not merely be tolerated in metallurgical literature; they should be the rule. While in chemical equations there is almost complete uniformity of notation all the world over, it is not so in other branches of engineering. But the recent activity of electrical engineers in their endeavor to establish uniformity indicates that its desirability is at least clearly recognized.

A Logical Guess as to Coal Mine Explosion

In the last two winter months of the year 1907 there occurred four bad and serious accidents in the Appalachian coal field. The loss of life and prosperity was appalling. Nearly a thousand lives were extinguished and many thousands of dollars of capital annihilated. Investigation of the causes by State and national authorities disclose officially the fact that the explosions were due to the ignition of gases or of coal dust. This was a plain statement which even an ordinary engineer knew all along. The deeper-seated or primary causes are now brought out clearly by Mr. Carl Scholz in a paper published in the July issue of the *Bimonthly Bulletin* of the American Institute of Mining Engineers. The analysis of the conditions discloses that the "hygrometric condition of the atmosphere has the greatest effect upon the cause of the explosions." For example, mines in a high dry altitude are especially dangerous. The colder and drier the weather, the greater is the liability to danger.

* * *

Of course, the higher the coal of a mine is in volatile matter, the greater the tendency to explosion, and this, independent of any climatic condition, is a determining factor. It was further brought out that with the advent of improved ventilating machinery the mine explosions began to happen and that in the old mines ventilated by furnaces the explosions were, practically speaking, unknown. A study of the conditions of mines in Oklahoma shows that in a certain mine in winter with a temperature outside of 32 deg. Fahr. and a humidity of 95 per cent, the relative humidity of the air forced into the mine, where it assumed a temperature of round 62 deg. Fahr., was only 33 per cent. There must always be a certain amount of coal dust in the entries of even the best-managed mines and this will, of course, be pretty well dried up by the incoming dry air. The explosive force of dry bituminous coal dust is well known and a painful remembrance is carried by us in the awful explosion of this dust in a large cement works near New York City. With this in a dry pulverulent condition it is axiomatic to say that it is little less dangerous than gun-powder. We believe that this all is sound reasoning and conservatively can be called a logical guess as to the cause of coal-mine explosions.

* * *

A corollary to this is that English mines are safer because of the damp English climate. The effect of the English dampness on other business is marked. And American textile manufacturers began to make an artificial English fog by spraying water into the air of their plants in order to moisten it. The natural practical outcome of this is that all coal mines situated in the dangerous zone should have their air artificially

moistened to keep the dust wet and so safe from explosion. This will have the effect further of preventing the stratification of "fire-damp" or methane in the mines. We have given this paper of Mr. Scholz prominence because it is our belief that science and technology should elevate life and eliminate its hardships and dangers. Mr. Scholz's paper is a conspicuous example of the practical effect of ability of modern applied science to attain this end.

The Psychological Moment to Get Ready for Prosperity.

During an industrial depression, such as the one from which the country is just emerging, business conditions are entirely different from conditions of business pressure. Instead of buying in normal amounts every concern and every person have a tendency to pursue a hand-to-mouth policy of purchases. Only when exceptional bargains are offered do large sales ensue and then only on the part of the wise and courageous. The policy of retrenchment is in the air and, by our common psychological atmosphere, infects everybody. A much more rigid scrutiny of wants and values is now made. Everybody is working more and spending less. But above all, the money that is being spent is spent more judiciously. In the period of working under maximum pressure there was no time to look after many details. Then every manufacturer was forced to get the most out of his organization as it existed. Now in these dull times long-delayed improvements and changes in plant, process and organization are being made. The country is again getting ready for prosperity. An outward indication is that advertisements in recognized mediums of publicity are increasing rather than decreasing. It is quite apparent that the shrewd business man is trying first of all to hold his share of his trade and next to prepare for his share of the enlarged future trade by judicious use of the columns of such technical journals as have a high-class clientèle. Both in quantity, quality and tone, advertisements must present the wares well and fully to this rigid scrutiny of the buying public. In these dull days the manufacturers are looking carefully into all possibilities of increasing efficiency and reducing wastes by adopting methods and devices which were formerly considered interesting, but now become of actual importance. The country is getting ready to buy as well as to sell.

* * *

History of the past depressions proves conclusively that sound concerns which have taken advantage of slack times to effect improvements in process, plant, distributing and advertising departments, have reaped a harvest when the pendulum swings the other way. People with the right stuff in them are not now bewailing the lack of business. Next year when the good crops in the agricultural regions have come to market they will have the wherewithal and the desire to purchase largely according to their needs. No sane American need fear the question of an outlet for the production of this country's mines and mills next year. Good judges expect that with the improvement in producing facilities the future will break all previous records in metal production. Those that have not the foresight to accept this will lose by the lack of that discriminating quality. Judicious preparing for the future now will be rewarded manifold when the wheels of industry are running again at full speed.

The Iron and Steel Market.

August has not shown as much improvement in the iron and steel trade as was recorded for July. The most rational analysis of the movements seems to be that the general swing is upward, but with only a very slight trend, while there are movements in alternate directions from week to week or fortnight to fortnight.

Discussion of the iron and steel situation this year has run a great deal to percentages, and in some cases the period establishing the basis, or 100 per cent, has not been clearly stated. Assuming as representing full operation the first ten months of last year, productive activity during the first half of this year was a trifle above 50 per cent, but as exports declined only slightly, production for the domestic market was slightly below 50 per cent. In July and August production has been between 55 and 60 per cent, but for the domestic market only has been between 50 and 55 per cent. There is little probability that the percentage of total production will rise above 65, or possibly 70 per cent at any time this year. The sharp turn is likely to come as the new year opens, and is reasonably certain to carry production to a point between 75 and 100 per cent.

This system of figuring percentages has a serious drawback, as it leaves out of the account two very important considerations. One is that in the past the iron and steel trade has not been prosperous in direct ratio to the percentage of production to possible capacity, because with production less than capacity prices have been relatively unremunerative, whereas for about ten months prices have been quite well sustained despite the inactivity, and it is a question whether the new order has permanently supplanted the old. The other consideration is that production during the first ten months of last year, while representing undoubtedly the maximum output possible with the then existent equipment, does not represent the prospective capacity at all, there being plants recently completed, or in shape to be completed within a reasonable period, to increase the capacity shown in the ten months of last year by 15 or 20 per cent. Under the old order of things demand would have to mount up to 115 or 120 per cent, under the nomenclature commonly used, to indicate full engagement of capacity.

The improvement which has occurred in demand for steel products has been chiefly in the light lines and in those which are taken by the largest class of consumers. The large buyers, who place single orders involving large tonnages, continue conspicuously absent. The condition was foreseen by the best market judges long ago. The financial panic affected the large buyers the most, and particularly affected such orders as have to be financed. Thus the railroads are buying very little, and there is little being done in large structural contracts for bridges and buildings. On the other hand, the demand for sheets has shown a very steady, although gradual, increase since the beginning of July. Wire products, which are usually very dull in the two summer months, make an excellent showing compared with the second quarter. Merchant steel bars, hoops, bands, etc., have been steadily gaining. The distribution of steel in the various finished lines has undergone a complete rearrangement in the past 10 or 15 years, and has even been greatly modified since the slight depression in 1904. These light lines constitute a much larger proportion of the total output than they once did, and the trade depends correspondingly less on large rail and structural orders.

This change promises a greater degree of activity for the trade than could be discerned at present if one judged by the old standards.

PIG IRON.

There was quite a movement in Southern iron since our last report, which quoted the market weak at \$12, Birmingham, for No. 2. Sales were made at \$11.50 for foundry iron, and a large tonnage of low-grade iron was taken up, chiefly by cast-

iron pipe interests. This caused a reaction about the middle of the month to a straight \$12 basis, and at the close of the month it is difficult to find any iron at this price, nearly all sellers quoting \$12.50 or \$13. The Central West has not given as good an account of itself, as prices have been sagging, in the case of Bessemer and basic in quite a pronounced way, considering the smallness of the tonnages which have induced sellers to make lower quotations, while in foundry and forge iron there has been only a slight recession. We quote prices f.o.b. Valley Furnace as follows: Bessemer pig, weak at \$15.25, against \$16; basic, weak at \$14.75, against \$14.25; foundry iron, \$14.50 on the sand ton of 2268 pounds, against \$14.75 on the gross ton of 2240 pounds; forge pig, \$13.75, against \$14. Freight to Pittsburg or Cleveland is 90 cents.

FINISHED PRODUCTS.

A statement believed to be entirely authentic is to the effect that before October 1 the Pennsylvania Railroad will place a large order for rails for 1909 delivery, thereby giving up all negotiations on a tonnage for the current year. February 6 it definitely tendered orders to the rail mills for 55,000 tons for this year, at the flat price of \$28, but subject to new and more rigid specifications. A month later it developed that the rail mills had not accepted the orders and the matter has since been hanging fire. The Pennsylvania has in recent years bought from 100,000 to 200,000 tons a year, and while its requirements for the current year were scaled down to 55,000 tons the prospects are that the order for 1909, really covering the requirements of two years, will be quite large. The placing of such an order would probably lead other railroads to place orders for next year.

Billets have been very quiet, the official price remaining at \$25, Pittsburg. It is believed that this price has been shaded occasionally through the medium of conversion deals.

Finished steel prices are unchanged, except that light rails are somewhat firmer, commanding \$24 to \$25. The "official" price of \$28 is no longer heard of, having been a dead letter for some time. We continue to quote:

Standard rails, 50 lb. and heavier, \$28.

Plates, 1.60 cents for tank quality.

Shapes, 1.60 cents for beams and channels, 15-in. and under, angles and zees; tees, 1.65 cents; large beams, 1.70 cents.

Steel bars, 1.40 cents, base. Iron bars, 1.40 cents, delivered Pittsburg; 1.35 cents, f. o. b. Pittsburg for western shipment, and 1.50 cents, Chicago.

Sheets, 2.45 cents net for black, and 3.50 cents net for galvanized, 28 gage.

Tin plates, \$3.70 for 100-lb. cokes.

Wire nails, \$1.95; plain wire, 1.70 cents.

Iron Ore Production of the United States.

The iron ore produced in the United States in 1907 amounted to 51,720,619 long tons, valued at \$131,906,147 at the mines, according to Edwin C. Eckel, of the United States Geological Survey, whose report on the production of iron ores, pig iron and steel has just been published by the Survey as an advance chapter from "Mineral Resources of the United States, Calendar Year 1907." Compared with 1906, this was an increase of 8.32 per cent in tonnage and of 31.21 per cent in value.

Iron ore is mined for blast-furnace use in only 29 States of the Union, though it occurs in almost every State and Territory, and by far the greater part of the ore is mined directly by pig-iron producers for use in their own furnaces. The valuation which is placed on the ore is, therefore, entirely a matter of accounting. Some of the reports made to the Survey evidently include merely actual mining cost, others contain an allowance for a sinking fund, and in still others the figures given are obviously merely convenient prices to use in charging costs against the blast furnaces. The errors that result from these various methods, however, are almost entirely in one direction—that of undervaluing the ore. If all of the iron ore

were to be bought by iron furnaces in open market from an entirely distinct set of iron-ore miners, the average prices paid would probably be considerably in excess of those reported. In 1907 these prices ranged, for brown ore, from an average of \$1.01 per long ton in Arkansas and Texas to \$3.67 in Connecticut and Massachusetts, and for red hematite from \$1.06 in Kentucky, Maryland and West Virginia to \$3.24 in Wisconsin.

Reports of production in 1907 were received by the Survey from 169 mines, the maximum production of any one mine being 2,900,624 tons, from the Hull-Rust mine in Minnesota. Ten mines, all except one being located in Minnesota, produced over 1,000,000 tons each. The million-ton mine not located in Minnesota was the Red Mountain, of Alabama, which during 1907 produced 1,370,849 tons and ranks seventh in the list of producing mines given by Mr. Eckel.

The producing States are grouped by Mr. Eckel into four natural districts, defined by geographic and trade considerations. These are (1) the Lake Superior district, which in 1907 produced 80.51 per cent of the total ore mined, and which includes Michigan, Minnesota and Wisconsin; (2) the southern district, which produced 12.4 per cent of the total ore, and which includes Alabama, Georgia, North Carolina, Tennessee, the Virginias, Maryland, Kentucky, Arkansas, Missouri and Texas; (3) the northern district, including New England, New York, New Jersey, Pennsylvania, Ohio and Iowa, producing 5.46 per cent of the total; and (4) the western district, producing 1.61 per cent of the total ore, and including the States of Colorado, Utah, Wyoming, New Mexico, California, Washington and Montana.

The stock of ore at the mines on Dec. 31, 1907, amounted to 3,033,110 long tons, as compared with 3,281,789 tons similarly held on Dec. 31, 1906, and 3,812,281 tons on Dec. 31, 1905. The detailed figures given by Mr. Eckel, however, show that while the stock on hand at the mines on Dec. 31, 1907, was about 250,000 tons less than on the same date in 1906, the stock on hand at the lower Lake ports indicated an increase of over 1,130,000 tons.

During 1907 the United States imported more than 1,200,000 long tons of iron ore. Of this total over half was from Cuba and about a third from Spain. About 116,000 tons came from British North America, and the remainder was from numerous smaller sources of supply. The exports during the year amounted to 278,208 long tons, a slight increase over the exports of 1906. The bulk of these exports represent Lake Superior ores shipped directly from the American side to Canadian furnaces.

The data on iron-ore production which form the basis of Mr. Eckel's report are collected directly by the United States Geological Survey, requests for statistics being sent to every producing mine in the country. The data on the pig-iron and steel industries, presented in connection with those of the iron-ore industry, are collected by the American Iron and Steel Association and published through the courtesy of that association and of its general manager, James M. Swank. According to Mr. Swank, the production of pig iron in the United States in 1907 amounted to 25,781,361 long tons, as compared with an output of 25,307,191 tons in 1906, and of 22,992,880 tons in 1905. The small increase shown by 1907 over 1906 is due to the falling off in demand and production during the last quarter of the year. If the output of the first half of the year had been maintained, 1907 would have shown a total production of about 27,000,000 tons.

The production of Bessemer steel ingots and castings in 1907 was 11,667,549 long tons, against 12,275,830 tons in 1906, a decrease of 608,281 tons. The total production of open-hearth steel ingots and direct castings in the United States in 1907 was 11,549,088 long tons, against 10,980,413 tons in 1906, an increase of 568,675 long tons, or over 5.1 per cent.

Mr. Eckel's report is ready for distribution and may be obtained by applying to the Director of the Geological Survey, at Washington, D. C.

Manganese Ores.

A recent report, published by the United States Geological Survey, deals with the production of manganese ore in 1907, the author being E. C. Harder.

The production of manganese ores in the United States in 1907 was 5604 long tons, valued at \$63,369. Compared with 1906, this is a decrease of 1317 long tons, or 19 per cent in quantity, and of \$24,763, or 28 per cent in value.

As usual, the bulk of the production—4604 long tons, valued at \$56,469—was in Virginia. South Carolina joined the ranks of producers for the first time since 1903, and its output of ore—800 long tons, valued at \$4,800—was greater than in any previous year. Tennessee and California also showed increased production in 1907. On the other hand, Georgia and Arkansas, which contain some of the most important manganese deposits in this country, were not among the producers in 1907. The Utah mines were idle throughout the year.

The larger part of the ore mined in this country in 1907 was used in the brick, paint and chemical industries, only about one-sixth (947 long tons, valued at \$6,747) being used in the steel industry, as against 209,032 long tons imported for this purpose. The main reason for this distribution of the product seems to be that although the demand in the first-named industries is limited, the prices paid are higher and ores can be used which would be undesirable in steel manufacture. Besides, the mining is on so small a scale that the supply does not run far ahead of the demand in these industries.

The small domestic production of manganese ores and the small portion of even this product used in making spiegeleisen and ferromanganese makes the importation of foreign manganese ore a matter of considerable importance to the iron and steel industry of this country. The imports for 1907 amounted to 209,032 long tons of manganese ore, valued at \$1,793,143, a decrease in tonnage, but an increase in value as compared with those of 1906, indicating that the price of foreign manganese ore has risen.

Ferroboron Prize Competition.

As was briefly noticed in our last issue, the rules for the ferroboron prize competition have recently been published. We now give them in full:

The sum of \$500 has been paid by the Pacific Coast Borax Company to the American Electrochemical Society and deposited in trust as a research fund to be awarded as a prize under the following conditions:

The Pacific Coast Borax Company desires to awaken an interest in research work which may lead to some improvement in the commercial method of manufacturing ferroboron by a direct process from colemanite.

It is essential that the process should be sufficiently economical and suitable to be applied on a large scale so that the finished product may be available for commercial purposes. (Commercial ferroboron, as now made, contains 20 per cent or more of boron, less than 3 per cent of carbon, and sulphur and phosphorous are practically absent.)

The prize has been deposited with the American Electrochemical Society, with the request that the Board of Directors award the same for the best practical solution of the problem, under reasonable conditions, to be decided upon by the Board of Directors.

In accordance with the above request, competitors for the prize are notified that they must comply with the following conditions:

1. The treatise on the subject must be in typewritten form and accompanied by a sample produced by the process described in same.

2. The competition for the prize is open to any one and is not restricted to members of this society. The treatise on the subject must be enclosed in a plain, sealed envelope, not bearing the author's name, but identified by a pseudonym. The

outside of the envelope, containing the paper, must be labeled with the pseudonym and with it should be sent another plain sealed envelope, also labeled with the same pseudonym, which should contain inside the envelope the name and address of the competitor. Both these envelopes should be sent to Prof. Morris Loeb, 273 Madison Avenue, New York City.

3. All papers competing for the prize must be in the hands of Prof. Loeb before Oct. 1, 1909. Prof. Loeb shall retain the small sealed envelope, containing the address of the competitor and forward the large envelope, containing the treatise, as well as the sample of the product, both merely labeled with the pseudonym, under cover, to the secretary of the American Electrochemical Society, to be submitted to the Board of Directors, who will award the prize. In this manner, as the treatise must be typewritten, the board can act with entire impartiality and the paper shall be judged on its own merits, so that the author's standing can have no influence whatever on the decision. The competitors for the prize forfeit none of their property rights in the process submitted.

4. As soon as the Board of Directors has agreed upon the best treatise, it will request from Prof. Loeb the address of the author thereof, who will then be required to demonstrate his process before the prize will be finally awarded.

5. The Pacific Coast Borax Company, 100 William Street, New York City, has offered to supply any one who desires to compete for the prize seriously with all the crude colemanite that the parties making the experiment may require, provided that the request for this colemanite be accompanied by a letter signed by one member of the Board of Directors of the American Electrochemical Society, endorsing the application for the material. This condition is merely made so as to furnish the material only to those who may have the proper qualifications to experiment intelligently and with some chance of success.

For the convenience of competitors who may desire to consult some of the published literature on the subject a brief bibliography is herewith attached.

H. Moissan and G. Charpy, *Sur l'acier au bore*, Comptes Rendus, 1895, vol. 120, p. 130.

M. L. Guillet, *Les aciers au bore*, Revue de Metallurgie, August, 1907, vol. 4, pp. 784 to 796 (translated in abstract in "Electrochemical and Metallurgical Industry," 1907, vol. 5, p. 421).

A bibliography on boron and borides in general may be found in O. P. Watts, an investigation of the borides and silicides, Bulletin University of Wisconsin, No. 145 (Engineering Series, vol. 3, No. 3, 1906).

CORRESPONDENCE.

Radioactivity.

To the Editor of Electrochemical and Metallurgical Industry:

SIR:—Some years ago you published in your vol. 2, p. 160, a letter from me in which I suggested that the sensible heat shown by the salts of radium might possibly be produced by some unknown rays from some extraneous source to which the salts of radium are opaque or partially opaque, thus converting some of the energy of these unknown rays into heat rays and thus rendering them perceptible to our sensations and to scientific measurement.

It seems to me that it would be of interest, first, to see whether any substance could be found that would appreciably alter the difference in temperature between radium salts and the material in juxtaposition to them.

For instance, if a box of platinum would reduce the difference between radium and the surrounding objects to one-half the usual increment of temperature—all other conditions being alike—it would indicate that platinum was partially opaque to these unknown rays.

It would also be of interest to test the heat increment in a given specimen of radium salt under carefully determined conditions at various different points on the surface of the earth, thus learning whether the intensity of this unknown energy varies, as does, for instance, the intensity of the magnetic force, and whether the geographical distribution of the intensity of these unknown rays bore any relation to the geographical distribution of magnetic force, or had any connection with the inclination or declination of the magnetic needle.

GODFREY L. CABOT.

BOSTON, MASS.

Worlds in the Making.

To the Editor of Electrochemical and Metallurgical Industry:

Your editorial on "Worlds in the Making" in the August issue calls attention to a very interesting subject, namely, the increasing percentage of carbon dioxide in the atmosphere due to the increased consumption of coal, and the consequent effect on the increase of plant life. The truth of the argument cannot be denied. The open question is merely a quantitative one; that is, whether the effect is appreciable. I understand that we are taught that in the early history of this earth, when it was a molten mass, there was no free oxygen and that our present source of oxygen comes from the production of coal by the plants from the gaseous carbon dioxide. If this is correct, it must necessarily follow that when we have burnt up all the coal on this earth, the oxygen of the air will all have been consumed again and plant life will then again be the chief form of life on the earth.

There is, however, another slow, but sure action which is taking place and which also affects the chemical history of this "insignificant, tiny world of ours," and which was not mentioned in your editorial, nor have I seen it mentioned anywhere else, although it is quite possible that it has suggested itself to others also. I refer to the slow, but continuous increase of oxygen in our atmosphere, due to our artificial reduction of the oxides of metals found in the earth. By far the greater quantity of the metals which we produce are originally in the state of oxides from which we reduce them, chiefly iron. Among these should be included also the limestones, which we now use so largely in the production of cements, and which in this process give off carbon dioxide as a gas. All this oxygen has, since the formation of this world, been combined in solid form with the metals and has, therefore, never been available for animal life as atmospheric oxygen; this is now being set free in large quantities, generally in a form in which it becomes a part of our atmosphere. Only very little of it gets back into the earth in the form of solid oxides of the metals which we have reduced, as our stock of reduced metals is increasing very much faster than it is consumed by oxidation.

It is true that the oxygen thus obtained from the metals is first set free, as a rule, in the form of carbon dioxide, as most of our reductions consist in transferring the oxygen from the metal to carbon. But as is well known and as was pointed out in your editorial, the function of plant life is to reduce carbon dioxide to carbon (wood) and oxygen. Hence the setting free of this oxygen which was combined with the metals, involves the aid of plant life.

That the above argument is correct probably no one will deny, but there is naturally another feature involved, namely, the quantitative one. Is the quantity of oxygen, which we are now adding to the air, sufficient in amount to have any appreciable effect? Is plant life increasing at a corresponding rate so as to reduce this carbon dioxide to oxygen? Is animal life increasing faster than in proportion to this addition to our oxygen? When left to nature, an oscillation or wave motion generally takes place, which oscillations ultimately die out, in this case the frequency being measurable in geological ages. Formerly, carbon dioxide was in excess and plant life consequently flourished,

setting oxygen free, thereby increasing animal life and diminishing plant life; the wave may now be reaching its turning point, the carbon dioxide increasing again, and if continued would decrease animal life and increase plant life until another turning point is reached, and so on, each oscillation being likely to be less than the preceding one. The changes are so slow that it need not trouble the present generation and is therefore only a matter of interest to us and not a matter of concern.

Those who are engaged in the good work of urging the preservation and extension of our forests, can add to their other good arguments, that plant life should be encouraged in order to check the increased percentage of carbon dioxide and to enrich the oxygen by setting free that which we are getting from the metallic oxides of the earth.

PHILADELPHIA.

CARL HERING.

* * *

Treatment of Iron and Steel in the Electric Furnace.

To the Editor of *Electrochemical and Metallurgical Industry*:

SIR:—It does not appear from the interesting article by Major Stassano on the "Treatment of Iron and Steel in the Electric Furnace," published in your August issue, that the assertion made in the note on "The Lash Steel Process and the Electric Furnace" (your vol. 5, No. 11, p. 455) is altogether incorrect, although that is apparently the intention of the article.

The assertion in question was to the effect that at the present time the direct production of steel from ore in the electric furnace is not commercially feasible on account of certain technical difficulties. The disagreement in the matter is possibly one of words, for it will be observed that Major Stassano speaks of having solved "the difficulties which interfere with the practical solution of the problem." Much depends upon the meaning to be attached and to the expression, "practical solution."

According to Major Stassano's work the consumption of power in the direct production of steel from the ore amounts to 4 kw-hours per kilogram at the least, and the cost of lining the furnace amounts to \$1.93 per ton of output. While there are doubtless places where electric power can be developed very cheaply, and while no doubt in the future this very cheap power will become somewhat more common than it is at present, it is generally wise in calculating the cost of electric furnace processes to arbitrarily assume that electric power at the furnaces will cost \$15 per horsepower-year.

If then 4 kw-hours are used per kilogram of steel the energy required for producing one ton (2000 lb.) would be 4880 hours, which would cost \$8.37, and thus the cost of power and furnace lining alone would, according to Major Stassano's results, be \$10.30. Except in special cases, or for the production of special grades of steel, this charge would prevent the commercial application of the electric furnace.

According to experiments made with the Lash Process, so far as these have gone, the total cost of treatment in the electric furnace is very much less than that calculated for power and lining from Major Stassano's results.

FRANCIS A. J. FITZGERALD.

FITZGERALD AND BENNIE LABORATORIES,
NIAGARA FALLS, N. Y.

* * *

Steel Foundry Practice.

To the Editor of *Electrochemical and Metallurgical Industry*:

SIR:—In reproducing the photograph (Fig. 2) showing test specimens in connection with my letter on "Steel Foundry Practice," published in your August issue, I see that the descriptive heading, "Unannealed Basic Open-Hearth Cast Steel," was omitted. This leaves the article without any mention of the fact that the test pieces were not annealed, and as that is really the only interesting feature about them, I

know you will be glad to rectify the unintentional omission of the word "unannealed" by giving space for this letter in your next issue.

R. A. BULL.

GRANITE CITY, ILL. * * *

To the Editor of *Electrochemical and Metallurgical Industry*:

SIR:—On the eve of sailing for Europe, permit me to say a few words in reply to Mr. R. A. Bull's criticism published in your August issue.

Mr. Bull accuses me of unfairness because of a statement that there was room for improvement and progress in making high-grade steel castings. I am not a foundry man and my remarks were simply based on what I was told by a great number of casting consumers; quite a number even told me that they were obliged to abandon steel castings owing to poor qualities and substitute forgings at a much higher cost.

To these makers it will no doubt afford a great relief to know that there is at least one concern and possibly more where they can obtain what they have been looking for in vain.

As to the excessive loss in the production of lighter steel castings and odd shapes, the information was given to me by a practical foundry man of a large company, who told me his company dropped the light-weight and odd-shape castings on account of heavy losses in the foundry. He fixed the average percentage of loss at 50 per cent.

I have no doubt that there are intelligent and progressive foundrymen like Mr. Bull, and I had, of course, no idea of underrating their merits. I merely desired to show how much better they could do if they had an opportunity to purify and refine their metal in an electric furnace. I did not intimate that the trouble was due to the foundryman's lack of intelligence, but entirely to the lack of sufficiently uniform and pure material.

As to the La Praz laboratory sheet I would say it is a part of a continuous run of a month's production to prove the purity of the metal we can produce from cheap raw materials.

The heats are all high-grade tool steel of a great variety of tempers with no idea of making them uniform. We, of course, can almost get exactly what we aim at in the Héroult furnace and can come much nearer to the mark than is possible in crucible or open-hearth practice.

In conclusion, I regret that Mr. Bull should have considered my incidental remarks relating to the steel foundry business in the nature of an attack upon himself and his associates. If he has been under that impression, I sincerely trust that the foregoing will entirely remove it.

After all, there is no harm in discussing questions of this sort; it can only be productive of good and further progress.

NEW YORK CITY.

* * *

To the Editor of *Electrochemical and Metallurgical Industry*:

SIR:—In your August issue there is a letter by Mr. R. A. Bull taking exceptions to Mr. R. H. Wolff's comparisons between electrical steel making and that of other steel-making methods. The writer agrees with both gentlemen that electrical smelting is destined to occupy a prominent position in steel making in the United States and would venture the opinion that the electric furnace's place will eventually develop as a valuable adjunct to established practice, such as the bessemer and open-hearth processes, by taking metal produced by them and submitting it to a greater degree of refinement than is possible by either.

Mr. Wolff's statement that the losses in steel-foundry practice are 50 per cent, may not be so misleading as Mr. Bull would have it. In Mr. Bull's opinion the statement is unfair. I desire, from a sense of fairness also, to prove that Mr. Wolff's statement has some elements of truth about it. The statement of such loss does not refer, as I take it, to one plant's practice, but rather to the steel-casting industry as a whole.

According to Mr. Bull's words the average yield is only 68 per cent on basic melting and included in the loss is an item of 4 per cent for defective castings. Mr. Bull's practice is not

that of a general product, but is mainly repetition work on specialties with a large percentage of it made on molding machines, and consequently the chances for high losses in defective castings should be reduced to the lowest possible figures. In a general or jobbing shop with a great variety of shapes the conditions are entirely different, as I will show. Mr. Bull has committed the error of thinking his practice as representative of the steel-casting industry at large.

The differences between metal charged and metal yielded varies with the shape and character of the castings turned out in salable form. Car fittings, such as bolsters, truck frames, etc., for both freight and passenger service, are comparatively light in weight, and will average about 600 lb. per casting. The loss in gates and risers on such designs is practically 7 per cent. Adding to that the loss in melting, skulls, fins and bad castings makes it comparatively easy to show a yield of 68 per cent of metal charged as good castings. Since Mr. Bull's product comes within the class of work just mentioned, a yield of the afore-mentioned figure is not exceptional, mainly because the kind of product does not greatly decrease the yield through a heavy loss in gates and risers.

Coming to a general or jobbing practice it will be seen that Mr. Wolff's statement is not wide of the mark. The writer has knowledge of a steel foundry producing a great variety of work which may be a small gear, the head of a molder's rammer or the sternpost of a *Dreadnaught*. The weight per casting may vary from a pound or two up to 100,000 lb. (one hundred thousand pounds).

In the particular foundry the methods are strictly up to date, the staff highly intelligent, progressive and alert, yet they think they are doing well if in a month's run on such contrasting shapes and weights the records show a yield of only 55 per cent of good castings from metal charged. The loss in bad castings does not exceed 5 per cent, but owing to a great many heavy castings, the loss in gates and risers is excessive. Large, massive castings require large, massive risers; bolsters, truck frames, knuckles and drawbars require small, light risers, and in some cases no risers at all. (It is the feature of heavy risers, resulting in a low yield, that has led Mr. Wolff to conclude that modern steel foundry methods are wasteful.) Take, for instance, a locomotive frame weighing 6000 lb. Such a casting necessitates a gate and risers totaling 2000 lb. An unavoidable loss of 33 per cent in non-salable metal. Other instances could be cited in support of such facts, which can be confirmed by progressive steel-foundry men.

A foundry report showing a certain loss in defective castings during a certain period may fluctuate through a variety of causes. A loss of one large casting would make a disastrous showing. Such a thing happens, yet the incident would not necessarily prove that the management was not progressive.

Another factor controlling a foundry report of good and bad castings is the system of inspection. It may be rigid or it may not. The inspection may be done by the plant's staff or it may be done on the ground by the customer. It is not the rule for the producer to inspect a casting from the customer's point of view. Conscientiousness varies with individuals. Records of replacements are not public property. Inspected castings are delivered to customers, but *sometimes* they are returned to the manufacturer and remelted. Pointing with pride to a month's report showing a low loss could be shamefaced if charged against it at a later period was one or more replacement orders.

Open-hearth methods have reached a creditable degree of growth in quality and tonnage. Like the Bessemer process they have practically reached the limit in the matter of quality. The product of to-day is the best that can be made with the materials and fuels available. The steps in open-hearth practice for future developments must come in the form of reducing the cost of repairs, simplifying the operation of furnaces, lengthening their life and producing larger tonnages with greater speed from larger sizes.

Mr. Wolff points out that losses in the steel-casting industry

are due to the sluggishness of the metal. That fault is not by any means common and if it does occur it is due entirely to operation under some adverse circumstance or possibly at rare intervals, the personal equation. If the furnace is in good repair, has the advantage of good fuel and stock, there is no excuse for sluggishness.

I am sure Mr. Wolff will agree that faults can occur with his electrical furnace and produce results equally as bad at times as can the open-hearth, the converter or the crucible. I will grant the gentleman that his device or process offers a possibility of yielding steel of *greater* purity and *better* quality than is possible by existing methods of steel manufacture, but I do not believe that he can with the assistance of his electrical furnace make the molder commit fewer errors, cause castings to strip more cleanly of burned sand, eliminate shrinkage and its attendant evils and *lessen* losses resulting from gates and risers.

Let the steel produced by *any* method be ever so pure or ultra-refined, the drawbacks cited (I could elaborate on them, but it is painful) will be like the get-rich-quick promoter, always on the job. I for one do not know that the American steel casting industry is in want of hotter or less sluggish steel. The methods we have give us that quality. But there is a burning longing for fewer losses of the kind above mentioned. The writer knows he voices the sentiments of American metallurgists in welcoming the adoption of the electrical furnace. He cannot refrain from the doubt that it promises greater yields, fewer bad castings and greater financial profits.

Since Mr. Bull's plea is one of fairness, permit me to refer to his chart of comparisons showing analyses of basic steel and electrical steel. It is the intention I take it to show progress in basic practice. The chart and the purpose of its comparison cannot be applicable to electrical furnace operation. It fails to show progress in basic practice.

No relation exists between unlike methods and unlike conditions. The chart marked October, 1900, refers to steel made in *tilting* furnaces of admittedly poor design, fired with producer gas. The practice at that time was the best that could be attained with the materials, furnaces and fuels. The chart marked May, 1908, refers to steel made in *stationary* furnaces fired with fuel oil. If Mr. Bull will refer to his records he will find that in the early part of the year 1900 the steel produced at that time was the best in the history of the company and at times showed losses fully as low and lower in defective castings than what Mr. Bull considers good practice at this date. In that respect alone there is not any evidence of progress.

In the 1900 chart the sulphur is shown as soaring to 0.054 per cent. On that particular occasion some very high sulphur coal was fed to the producers unknowingly. The reputation and record of the steel melter should not suffer if in 1908 the other fellow is so favored by circumstances as to have oil for fuel so low in sulphur that there is no contamination of the bath. Leaving out the one high sulphur heat in 1900, the year 1908 does not show any degree of desulphurization in the basic-open-hearth to the detriment of practice conducted eight years ago. The year 1900 kept below, in the maximum of phosphorus, standard specifications, but it went the 1908 chart 0.004 better in the refining of that element.

I trust you will give the foregoing remarks space in your publication, since from my point of view and acquaintance with steel foundry practice Mr. Bull has not refuted Mr. Wolff's arguments. Electrical methods are undoubtedly becoming recognized and your journal has done valuable work in disseminating knowledge concerning them. Therefore, in asking for your space, it is with the conviction that some few truths should be given your readers concerning steel-foundry practice from one who does not desire to put himself on record as "one who knows," but as one who wishes to know and that others may acquire, a few facts given without dissimulation.

NEW YORK CITY.

W. M. CARR.

Electrolytic Refining of Gold, Silver and Copper at the United States Mint, San Francisco, Cal.

By ROBT. L. WHITEHEAD.

Gradually all the mints have been equipped with electrolytic processes for refining their metals; Philadelphia first, then Denver, and now the sulphuric acid process, in use for over 30 years, has been completely replaced at San Francisco by the most modern equipment installed in any of the mints.

The system of refining as first installed at the Philadelphia mint, though largely experimental, developed the fact that the electrolytic method was cheaper, gave a purer metal for coinage and saved by-products of great value which by the old acid processes were either lost or remained in the finished coin.

The Denver mint was equipped by the writer two years ago with electrolytic refining processes. As shown by the report of the director of the mint for the fiscal year ending 1906, he considered this the most modern equipment in the service. From the experience and results obtained there, the writer was enabled to install in the mint at San Francisco an equipment which

The rolling and hydraulic press room is the next in order, the dimensions being 18 ft. x 40 ft. Opening from this room is a storeroom for supplies. The vault for storing all the metals in the foreman's charge not actually in the process of refining has a convenient location in this room.

In the attic, access to which is obtained by a winding staircase from the rolling room, are located the condensing chambers for the melting furnaces, two Rockwell steam pumps for forcing oil to the furnaces, and a steel storage tank of 2000 gal. capacity. This tank is supplied with fuel oil by a force pump from the main storage tank in the street, which has a capacity of 10,000 gal.

The care and comfort of the men has not been overlooked, as toilet, shower baths and dressing rooms are provided, which open directly into the operation rooms. In order to give an intelligent idea of the equipment it will be necessary to take each room separately.

The Tank Room.—(Fig. 1.) The floor of this room is laid with acid-proof stone slabs, 2 in. thick, the joints being litharge and glycerine cement, which in reality is waterproof, but not acid-proof. The Wohlwill process for gold refining is used, the same process for gold refining being applied in all the mints. (See the articles by D. K. Tuttle and E. Wohlwill, this journal, Vol. I, p. 157, and Vol. II, p. 221 and 261.) For this equipment 30 specially designed Royal Berlin porcelain tanks, 18 in. long, 13 in. wide and 12 in. deep, are arranged on a 2-in. stone table, which is supported by white enamel brick pillars. The tanks are arranged in two rows of 15 tanks each.

The circulation is obtained from an individual flow from a porcelain trough, which is supplied from a jar 36 in. x 24 in. in diameter, which receives the discharge from a porcelain plunger pump made specially to withstand the chemical action of chloride of gold solution containing free hydrochloric acid.

The pump, as shown in Fig. 2, has an overflow pipe from the discharge jar into the pump tank. This prevents a "spill." Tops are provided on the troughs, discharge and pump tank to prevent spattering and cooling.

By adjusting a spigot in the bottom of the discharge jar, the flow to the trough is regulated. The flow to each tank is regulated by the openings from the trough; the tanks are so constructed that the solution enters the back end of the tank and draws from the bottom, thereby constantly removing the heavy gold chloride, which sinks to the bottom, into a trough which carries it to the pump tank to be circulated again.

By this arrangement of circulation each tank has its own individual flow of electrolyte, and can be regulated fast or slow as conditions warrant, thereby obtaining a uniform mixture of solution which is both quiet and constant. This is in striking contrast to the propeller circulation in use in the other mint refineries. This arrangement makes it easy to properly take care of the electrolyte, as there is only one solution for the tanks. A few assays a day is not very much. But when it amounts to 50 the result may be that no tests are made of the solution for months at a time, and the man in charge of the tanks is governed entirely by the character of the deposit, while all the time he may have 1 or 2 per cent more gold in solution than is necessary.

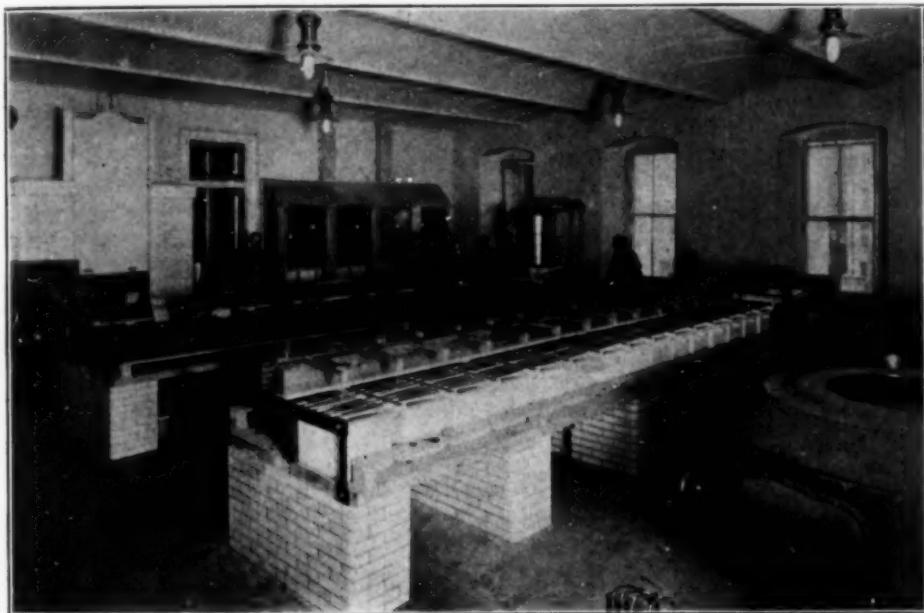


FIG. 1.—TANK ROOM.

far exceeds the Denver equipment, both in size and with respect to improvements, so that the San Francisco mint is now the most up-to-date plant of its kind anywhere installed.

The allotment of rooms set apart for this purpose by the superintendent has greatly added to the efficiency of the equipment. For each distinct operation a separate room is provided so that the element of crowding, which is so apparent in the other mints, has been eliminated. The tank room, which is 41 ft. x 52 ft. in size, has windows on both sides. This insures proper ventilation and a working atmosphere comparatively free from fumes.

The generator room has dimensions of 16 ft. x 26 ft., with three windows. In this room are located four motor-generator sets and a controlling switchboard.

Three rooms are set aside for the laboratory of the refinery. The smelting room is 34 ft. x 30 ft. in size and also has windows on either side. In some respects this is a disadvantage, since the fine dust that invariably floats around melting rooms will be taken out by the draught.

An office and weigh room for the foreman opens into both the melting and rolling rooms. All metals received for refining are first weighed here before receipting for them, and also all fine metals are weighed before delivering to the melter and refiner.

sary. Those in charge of outside electrolytic plants will appreciate the force of this argument.

As the objections to the propeller system of circulation are so numerous and will not interest the readers of this article, I will only mention a few. First, the violent agitation is confined to one place, leaving the ends of the tank with very little circulation and hastens the formation of slimes. The chloride of silver formed on the anode is dislodged and floats around the tank; some of it adheres to the cathode and is covered up with

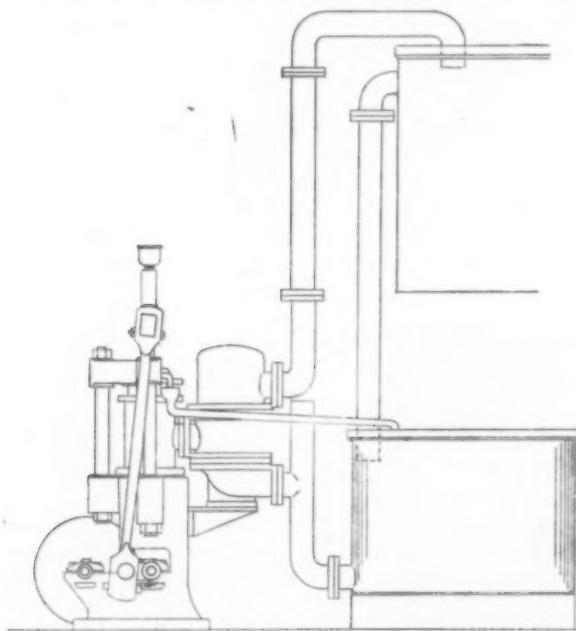


FIG. 2.—PORCELAIN PUMP AND CONNECTIONS FOR CIRCULATION OF GOLD ELECTROLYTE.

fresh deposit, or if sufficiently large forms a short-circuit. The most serious objection, however, is the swirl of the solution which throws the slimes to the ends of the tank and gradually causes short-circuits, so that more frequent shut-downs for cleaning out are necessary. The space in the tank occupied by the propeller rigging robs the tank of depositing surface, curtailing the production per tank.

A majority of these objections are overcome by the trough circulation. This does away with the objectionable feature of

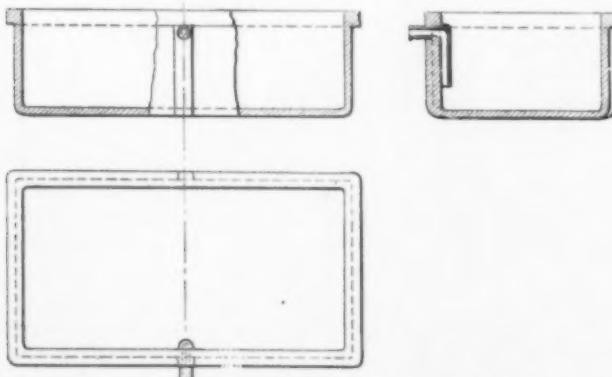


FIG. 3.—EARTHENWARE TANKS FOR SILVER SOLUTION.

putting gold chloride acid into each tank with a pitcher. When it becomes necessary to enrich the electrolyte the proper amount can be added to the pump tank and the same may be done with acid, while, when it is necessary, to draw off the foul solution, this can be done from an opening in the end of the trough without disturbing the operations in the tank. The anodes and cathodes are $\frac{3}{4}$ in. apart, requiring only 1 volt per tank to main-

tain 450 amp. This gives a current density of 105 amp per square foot of cathode surface, giving an output of gold per 24 hours per tank of 650 to 675 oz. The best run for one week with 20 tanks in circuit was 13,500 oz. per day. The fineness of the melted cathodes averaged 999.5.

The purity of the anodes varied from 880 to 900 in gold. Anodes having as much as 100 pts. of silver have been worked successfully producing gold 999 in fineness.

The silver tanks (Fig. 3) are of German earthenware and a similar arrangement of circulation is employed. For this purpose an earthenware centrifugal pump is provided, as shown in Figs. 4 and 5. The horizontal or Thum system of parting silver is used. It will only be necessary to describe the new features attached to it as the details of the process are well known to the readers of this journal.

The tanks are 24 in number and are $39\frac{1}{2}$ in. long, $19\frac{1}{2}$ in. wide, 12 in. deep, arranged on a 2-in. stone platform supported by enamel pillars, the construction being the same as that of the gold-tank foundations. The anodes are made up 300 and 333 pts. gold, not over 100 pts. base, the balance being silver. The

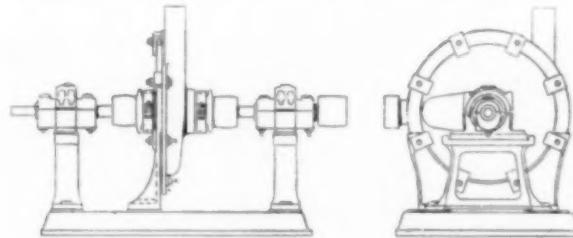


FIG. 4.—CENTRIFUGAL STONEWARE PUMP FOR SILVER ELECTROLYTE.

electrolyte contains from 1 to 2 per cent free nitric acid, $3\frac{1}{2}$ to $4\frac{1}{2}$ per cent silver, besides lead, copper, bismuth and zinc. As the anodes are very base, about 5 per cent by volume of the electrolyte is drawn off each day and an equal volume of solution very rich in silver is added. This is sufficient to keep the electrolyte pure enough to make a coarse, sugary deposit.

The trough circulation is used in the silver tanks to the same advantage as in the gold tanks. The electrolyte having a uniform composition, practically the same current density is kept in each tank, about 50 amp per square foot of anode surface.

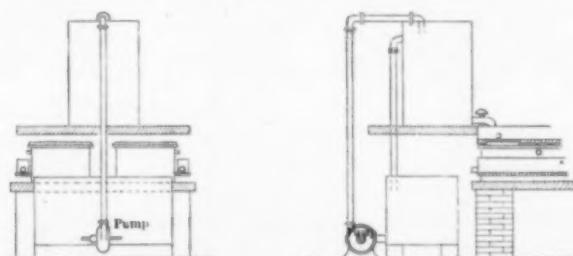


FIG. 5.—PUMP AND CONNECTIONS FOR SILVER TANK.

The anode contact piece is cast into the anode slab, thereby obtaining a more perfect contact. The current going directly into the slab acted upon, one set of contact pieces is sufficient, for as soon as the slab into which it is cast shows disintegration it is cast into a fresh slab.

The foul solution that is drawn off is freed from silver by copper plates. The silver thus recovered is used in making silver nitrate to replenish the electrolyte. The waste solution is sent to the iron tank to recover the copper.

The deposited silver runs uniformly about 999.5 in fineness, the anode residue of gold is washed free from silver and melted and cast into anodes varying in fineness from 920 to 950 in gold. It will be observed that there is no boiling with nitric acid.

In the refineries of the other mints the devotion to old methods with which the men are familiar, is still shown by the fact

that the foul silver solution is purified by precipitating the silver with salt as chloride. The copper present as nitrate is run into the sewer, this metal apparently having no value because the government has not paid for it. At the same time, should platinum in small quantities go into solution, it would be lost through the same channel.

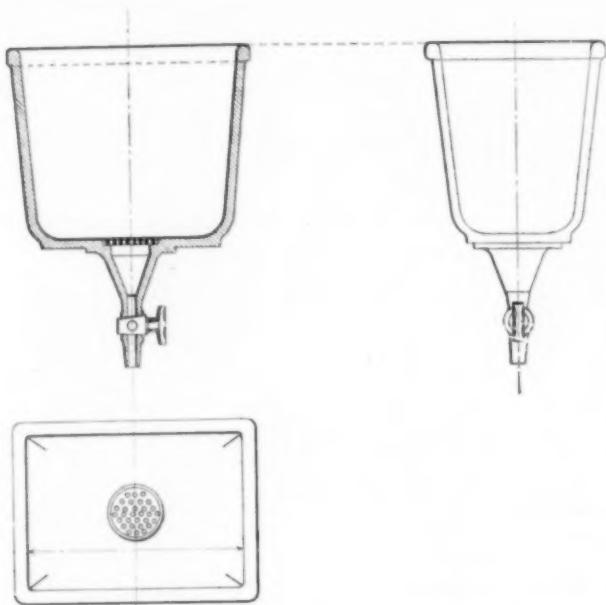


FIG. 6.—PORCELAIN AND EARTHENWARE FILTERS, MOUNTED ON BRICK.

By using the proper equipment and a little care the copper can all be saved. The recovery of silver as chloride is a relic of the old nitric acid process, which served its purpose, but in this age of advancement should be a thing of the past.

In this room all the products of gold and silver, except tops and cathodes, are washed in earthenware centrifugals. The

handled with ease and can be readily melted in plumbago crucibles, if rich in values.

The entire porcelain and earthenware equipment, as well as the centrifugal washers and dryers, were furnished by J. W. Sitting, of New York, who has supplied the government with this ware for a number of years.

The system of making gold chloride, which was worked out by the writer previous to the installation of the Denver refinery, is now in use in the different refineries of the mints.

The process consists in passing an electric current through a solution of strong hydrochloric acid (no nitric acid being used in the solution) with anodes of gold, 990 or over in fineness, while the negative pole of the circuit is connected to a cathode of rolled gold suspended in a porous cup filled with strong hydrochloric acid, the cup being immersed in the bath. The current is forced through the bath at a pressure of 5 volts. During the operation considerable heat is generated, the cathode surface being small for the high current used, namely 200 amp at 5 volts.

There is considerable evaporation of acid, both in the bath and the cup, and the bath has to be replenished with acid from time to time. An acid-proof stone hood is used for this operation, which is shown in the photograph of the tank room, Fig. 1.

In this hood are five porcelain tanks. They are 24 in. long, 15 in. wide and 15 in. deep. They have a capacity of 2000 oz. per day of fine gold. This equipment is larger than is necessary, so that ample time can be taken to properly care for the operations of the process, and keep an ample supply of gold chloride always on hand.

There are in this room three lead-lined tanks, each 36 in. long, 18 in. wide and 18 in. deep, which are used for copper electrolysis. The copper recovered from the nitric and hydrochloric acid solutions contains gold, silver and platinum metals and is treated electrolytically to obtain copper sufficiently pure for alloy, the gold, silver and platinum being found in the slimes. The slimes from the copper tanks are treated separately and melted into a bar, which is worked up separately to recover the platinum, which in a year's time amounts to about 400 oz.

As the deposits contain only a very small amount of platinum, no effort is made to make a separation from the electrolyte with sal ammoniac. After the gold has been precipitated with ferrous chloride and sulphate, the platinum is thrown down with the copper by scrap iron.

As will be noticed from this article, the refining at the United States Mint in San Francisco is entirely electrolytic. Nothing either in the equipment or operations reminds one of the sulphuric or nitric acid processes, while the refineries in the other mints still adhere to boiling and precipitation methods.

A method for refining the gold slimes produced in the Wohlwill process was perfected, and 12 additional tanks were ordered to take care of this process. This method is also entirely electrolytic, but it is too early to describe it further.

The system of removing the copper from the nitric and hydrochloric acid solutions is quick and very complete. A lead-lined tank,

7 ft. long, 4 ft. wide and 4 ft. deep, contains a perforated lead basket, filled with scrap iron and suspended two-thirds the depth of the tank. An earthenware siphon pump pumps the solution over and over, until free from copper. After settling, it is run into an intermediate settling tank before going through the

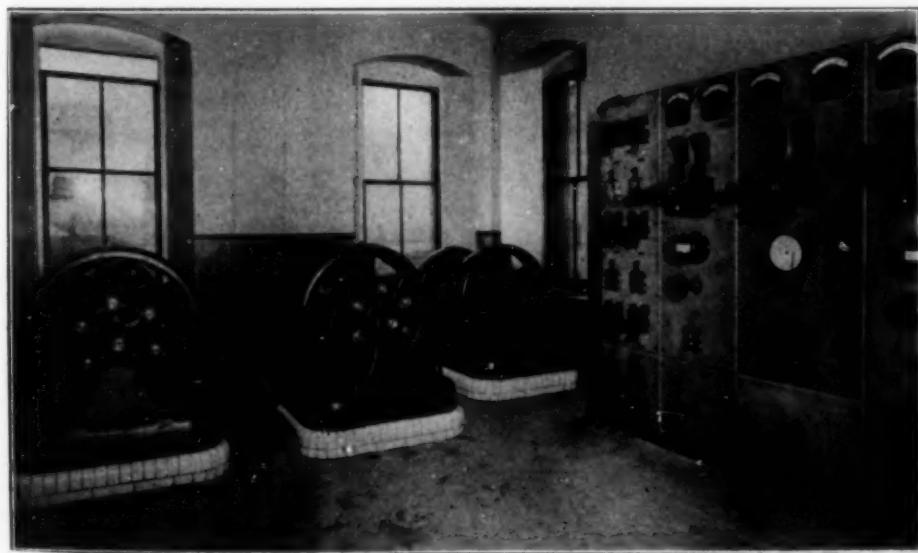


FIG. 7.—GENERATOR ROOM.

washing is very quick and complete, and the precipitates are sufficiently dry to put in a melting pot without further drying.

This is the first mint to use this system of washing, which has proved highly satisfactory. Cement copper, which is one of the most difficult products to wash free from iron salts, is

two settling tanks in the yard and then into the sewer.

The general opinion is that the nitric and hydrochloric acid solutions dissolve the lead lining of the tanks, but a hard-lead lining of special composition is used, and after three months of hard use in contact with boiling solutions containing both acids in the free state neither tank has developed a leak.

The ferrous chloride formed in precipitating the copper furnishes two-thirds of the iron salt necessary to precipitate the gold from the foul solutions.

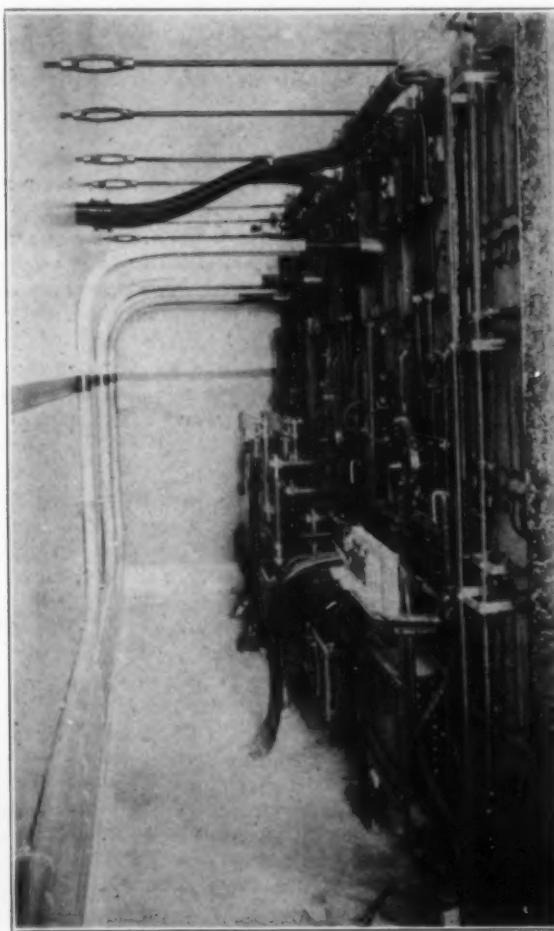


FIG. 8.—BACK OF MAIN SWITCHBOARD.

During three months' operation of the refinery 500 lb. of copper was recovered from the gold operated upon. From this copper 112 oz. of platinum and iridium were recovered. The slimes from the copper electrolysis produced a bar assaying 83 parts of platinum per 1000 oz. This represents a concentration from 1,073,000 standard ounces of gold, which, if the platinum were evenly distributed, would make less than one-tenth of a point per 1000 oz.

The next in point of importance is the **generator room**, Fig. 7. There four motor-generator sets are located, as follows: Two sets produce 1000 amp at 15 volts, one each for gold and silver. One set for gold chloride electrolysis gives 500 amp at 25 volts, and one set for copper gives 200 amp at 6 volts. Each set is built for voltage regulation, so as to obtain the maximum load in amperes from 5 to 15, from 5 to 25 and from 2 to 6 volts.

Each of the large sets can be operated independently on either the gold or silver tanks, or both sets can be used together on one system; or one set at a time can supply current to both gold and silver tanks. By this latter arrangement the highest efficiency can be obtained from the machine when the refinery is not running at its full capacity, and at the same time one set will always be idle. As the gold chloride set is not running continuously, ample time can be found for repairs without inconvenience to the operations in the tank room.

The switchboard, the location of which is shown in the photograph of the generator room, Fig. 7, consists of seven panels of acid-proof stone, three motor panels and three generator panels, with one panel for controlling the auxiliaries in the refinery, namely: two small motor-generator sets; two centrifugals with a 5-hp motor on each; one elevator for filtering purposes, operated by a 5-hp motor; one rolling mill with a 15-hp motor; two pumps with a $\frac{3}{4}$ -hp motor on each; one hydraulic press with a 5-hp motor; one Sturtevant fan blower with a 10-hp motor.

The total length of the board is 15 ft. 6 in., and the height from the floor is 8 ft. The board is equipped with the usual instruments for controlling the motor-generator sets, and, in addition, each motor panel has a Sangamo watthour meter for registering the watthours consumed by the motor on each individual set. Each generator panel also has a Bristol recording ammeter which shows on the chart the current in amperes delivered to the different electrolytic systems. It suffices as a check on the night forces so that the required amperes are kept on the tanks. It is also used for determining the commercial efficiency each week on the different systems.

While these features of the equipment are considered by the older men in the service as "frills" and entirely unnecessary, they have the advantage of showing up the weak points in the operation, which more often efforts are made to cover up.

The motor panels are fed by separate circuits from the main switchboard in the basement. The circuits are run so as not to be seen except at the point of entrance to the room either in the attic or in conduits under the floor. No pipes, either for steam or water, or wires are strung overhead, all being safely protected from acid fumes, as will be seen by close inspection of the photographs of the different rooms.

The terminal leads from the generators to the board are lead-covered, paper-insulated cables with a carrying capacity of 25 per cent overload. The leads are bracketed to the wall, as shown by the photographs of the back of the board, Fig. 8. The connections are specially designed heavy copper lugs. The cables to the tank room run through a pitched conduit under the floor and come up to the tank connections through the middle of the enamel brick supports to specially designed lugs which are enclosed in stone slab boxes, 6 in. each way, and filled with beeswax and rosin. This is poured in hot and forms a perfect insulation from the acid of the electrolyte in case of a "spill."

The return cables are equipped with the same kind of box and lug arrangements. The lugs connect to 4-in. x 8-in. copper busbars, into which the necessary individual connections for the tanks are made.

The 30 gold tanks are connected in series in two sets of 15 each, 500 amp passing through each set. For the 12 silver tanks a series-parallel connection is used.

The small board for regulating the current to the copper tank, which is shown in the photograph Fig. 9, is enclosed in a glass case and is located on the wall of the tank room close to the copper tanks.

The **laboratory** (Fig. 10) is equipped with the latest apparatus and devices for handling all the work in the refinery, and further enables the chemist in charge to experiment and solve



FIG. 9.—COPPER-TANKS BOARD.

the many questions which constantly arise in all electrolytic processes.

A small motor-generator set, giving 50 amp at 2 to 6 volts and a controlling board for electrolytic determinations and experi-

the aid of a portable voltmeter. The tanks in the different systems are numbered consecutively, namely: the gold chloride from 1 to 6, the gold tanks from 1 to 30, the silver tanks from 1 to 12; these numbers correspond to numbered hard-rubber



FIG. 10.—LABORATORY WORK ROOM.

ments, furnishes a very necessary and important piece of apparatus.

The photograph, Fig. 10, gives a good idea of the laboratory workroom, which is separated from the private laboratory and

push buttons on the board. Each system has a separate voltmeter connection. The voltage on any tank is shown by simply pushing the button corresponding to the tank. The button is so constructed that by a turn the contact will remain fixed. In 10 minutes' time the operator can determine the voltages on the three systems, while to determine the voltages by a portable voltmeter would consume at least an hour and two men's time. The workmen have found this board of great advantage in locating short-circuits and irregular workings in the tanks. Over

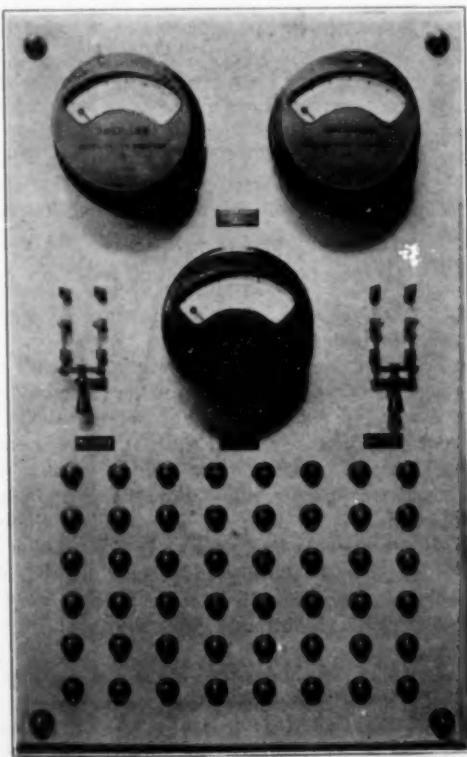


FIG. 11.—TEST BOARD.

balance room by a glass partition. In this room is a small test board, shown in Fig. 11, which was specially designed at this mint. The purpose of the board is to quickly determine the voltages on the different tanks in the different systems without

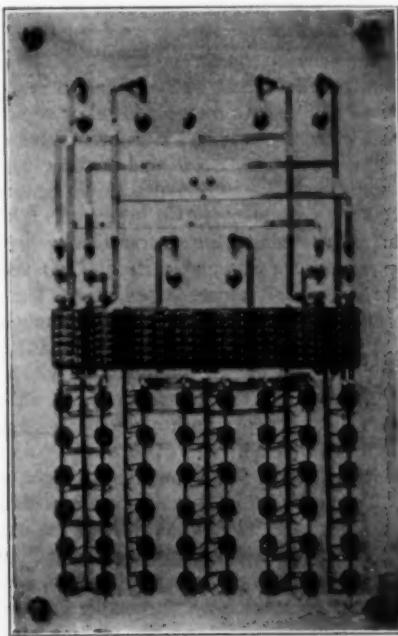


FIG. 12.—BACK OF TEST BOARD.

5000 ft. of wire was consumed in making the connections to the different tanks. The photo of the back of the board (Fig. 12) shows the arrangements of connections and contacts.

(To be concluded.)

New Thermit Reactions*

BY HANS GOLDSCHMIDT, PH.D.

The object of this paper is to demonstrate some new thermit reactions, the main feature of which is the substitution of other elements or alloys for aluminium in the aluminothermic reaction.

I will first give my definition of a *thermit reaction*: "In a thermit reaction a metallic compound is reduced by one or several metals or metallic alloys in such a way that when the mixture is ignited at one place, the reaction continues to go on spontaneously with complete oxidation of the reducing element, a fluid slag being formed, while the reduced metal is obtained as a compact uniform regulus; if the oxide is used in excess, the reduced metal is free, or practically free, from the element used as reducing agent."

This definition seems lengthy, but it emphasizes two features which are most important from an engineering standpoint—namely, the production of a fluid slag and a uniform, compact regulus of metal.

As is well known, thermit reactions are being employed on a large commercial scale for the production of chromium, manganese, molybdenum, etc., but especially for getting technically pure iron, free from aluminium and carbon, in a fused and exceedingly hot condition for welding and repairing purposes. Since the introduction of the thermit rail-welding process several years ago some 200,000 joints have been made by this method.

At the International Congress for Applied Chemistry in 1903 I discussed the possibility of employing metallic silicon (made in the electric furnace) as a substitute for aluminium in the thermit reaction. I showed that silicon cannot be successfully used in this way. For instance, if a mixture of equivalent parts of silicon and Cr_2O_3 or Mn_2O_3 is ignited, the reaction will not proceed. With a mixture of Mn_2O_3 and silicon it is possible to obtain a reaction similar to the thermit reaction, but, however large an excess of Mn_2O_3 may be employed, it is impossible to eliminate the silicon. Some per cent of silicon will always be found in the manganese.

With ferric oxide (Fe_2O_3) the reaction, when once started, will continue slowly if the silicon is used in a very finely divided state, while with Fe_2O_3 (as used in ordinary thermit) no reaction is obtained with silicon.

It is possible to reduce lead and copper by means of silicon from mixtures of silicon with oxides of lead or copper, but these reactions have hardly any practical interest. In the case of copper, the reaction is relatively slow and the slag contains white globules of a copper silicide with about 10 per cent of silicon; a small quantity of pure copper is also produced. The lead reaction is similar; it proceeds with a strong development of smoke.

If, however, a mixture of equal parts of CuO and PbO with Si is treated, the reaction proceeds properly. The reaction of such a mixture is similar to that of thermit, although it is much slower. A compact regulus is obtained with a fluid slag. The metal is obtained in two layers, the lower of which is an alloy of equal parts of Pb and Cu, with traces of Si, while the upper layer consists of brittle copper with about 10 per cent of silicon and small quantities of lead.

As far as I know, Prof. Muthmann, in Munich, was the first who successfully carried out a new reaction similar to the aluminothermic reaction. Several years ago he showed me in his laboratory a sample of pure regaline vanadium which he had produced by means of his so-called mixed metal (Mischmetall) which consists essentially of metallic cerium. (See the paper of W. Muthmann and L. Weiss on metallic vanadium, niobium and tantalum, published in May, 1907, in *Liebig's Annalen*, vol. 355.)

When the Bitterfeld works placed metallic calcium on the market (made by the electrolytic process described by Dr.

Rathenau; see this journal, Vol. II, page 276, and Vol. III, page 80), the application of calcium in thermit reactions naturally suggested itself. The first publication of experiments in this field appeared in the *Berichte der Deutschen Chemischen Gesellschaft*, Vol. 38, page 904, 1905, containing a preliminary notice by Ernst Beckmann on "some applications of metallic calcium." He states that calcium finely divided and used according to the Goldschmidt process, reduces certain metallic oxides and sulphides "with good success" to metal (for instance, manganese, copper, lead). I have carried out the reactions in my laboratory and I agree, in general, with Mr. Beckmann, although the meaning of his words "with good success" should be further interpreted. It seems that in this respect the opinions of the theorist and of the engineer clash.

In the above definition of a thermit reaction I emphasized the production of a fluid slag and of a uniform, compact regulus. But this is impossible with metallic calcium, according to my extended investigations and experiments. The reason is not far to seek. The calcium oxide formed is but slightly fluid, and although a certain number of small metallic reguli are obtained (for instance, in the reduction of iron oxide), yet a large part, and generally the major part, of the reduced metal is closely intermixed with the slag. This is a serious matter from the standpoint of the engineer, since on account of this "unclean" reaction its practical application for the production of metals or for welding purposes appears impossible.

I will now describe a series of novel reactions which fulfil all the requirements of the thermit reaction summed up in the above definition.

Calcium-Silicon.

To those experienced in thermit reactions it may appear natural to try to use calcium together with silicon for two reasons. The first is to produce an easily fluid calcium silicate slag. The second to combine the exceedingly turbulent calcium reaction with the slow silicon reaction in such a manner that a medium speed of reaction, best suitable for technical purposes, is obtained.

For a number of years I have carried out several hundred of such thermit reactions which are all more or less of interest to the thermit specialist. These investigations have been carried out by me jointly with Dr. Weil and his assistant, Dr. Müller. Since all these reactions are rapid, it is desirable that more than two eyes observe them. This paper is restricted, however, to a description of the most characteristic reactions only, and of their principle.

Magnesium-silicon acts in a similar way as calcium-silicon and a third suitable combination is a mixture or an alloy of calcium and aluminium.

The engineering value of a thermit reaction depends not only on the calorific effect, but also on the reaction velocity. Naturally, for metal reduction it does not matter how much time the reduction takes, provided the slag is sufficiently fluid and the metal has a sufficiently low melting point to flow together and form a compact regulus below the slag. If, however, a thermit reaction is to be used for welding, the reaction velocity is of considerable importance. If the reaction is slow, the reduced metal cools quickly and cannot be employed for welding. On the other hand, it is evident that a violent reaction, such as is obtained with pure calcium, cannot be made use of in practice.

I will now demonstrate a number of thermit reactions.*

$4\text{Ca} + \text{Fe}_2\text{O}_3$.—The calcium reaction is very violent. It does not yield a compact, uniform regulus of iron. The product is an intimate mixture of small metallic globules and slag.

$2\text{Si} + \text{Fe}_2\text{O}_3$.—This mixture cannot be made to yield a reaction which will go on satisfactorily.

Calcium-silicon thermit.—This reaction goes on almost in the same manner as the ordinary aluminium-thermit reaction, there-

*A lecture held at the Vienna meeting of the German Bunsen Society, May 30.

*These reactions were demonstrated experimentally by Dr. Goldschmidt before the Bunsen Society.

being hardly any evident difference, except that with the silicon-calcium thermit the slag is much more fluid and does not solidify as quickly as the corundum slag of the aluminothermic reaction. This is especially the case when the process is carried out with large quantities.

Naturally, the proportion of calcium to silicon has some effect on the result. A mixture containing equal quantities of Ca-thermit and Si-thermit (so that the active metals Ca and Si are in the proportion of about 2 to 1) is especially effective. This mixture yields a thinly fluid slag, a good metallic regulus and a comparatively high thermic effect.

In the calorimeter this calcium-silicon thermit evolves 720 calories, while the ordinary aluminium thermit evolves about 100 calories more. These figures are approximate and comparative figures only, and are not given as absolutely accurate.

If more calcium is used, than corresponds to the above proportion, the reaction becomes quicker and more violent, while the slag is less fluid. If, on the other hand, the proportion of the silicon is increased, the reaction is retarded.

Of course, the active mixture may be prepared by mixing the proper quantities of calcium shavings or filings with silicon. It is also possible to melt together metallic calcium and silicon under a suitable protective cover; the brittle alloy which is thus obtained, is then powdered, if it does not disintegrate to powder spontaneously.

However, these methods of preparing the calcium-silicon are costly, since metallic calcium made by electrolysis is not inexpensive. On the other hand, metallic silicon can be made in the electric furnace at very low expense. It is possible to buy the kilogram of silicon new for 1 franc (about 20 cents), and if more applications could be found for silicon, the price could be reduced still further.

Moissan and Dilthey (*Berichte der Deutschen Chemischen Gesellschaft*, Vol. 35, page 1106) heated silicon mixed with lime in an electric furnace to a high temperature and produced a calcium-silicide which always contained CaO_2 . Moissan (*Comptes Rendus*, Vol. 127, page 584) obtained a calcium silicide with some 20 per cent calcium and a considerable quantity of carbon.

I have succeeded in making a calcium-silicide containing more than one-third of metallic calcium, without making use of the electric furnace. (Concerning the properties of this calcium-silicide and its application for the purification of metals, especially steel, see the June issue of this journal, page 244.)

Magnesium-Silicon.

$4 \text{Mg} + \text{Fe}_3\text{O}_4$.—Magnesium thermit reacts like calcium thermit, while a mixture of magnesium and silicon gives a reaction similar to ordinary thermit. Concerning investigations by Clemens Winkler in this field, more than 18 years ago, see *Liebig's Annalen*, Vol. 301, page 1971, also *Berichte*, 1890, Vol. 23, pages 44, 120, and *Journal für Praktische Chemie*, 1864, 91, 199.

Naturally there are certain proportions between Mg and Si which are especially suitable for a thermit reaction, but it is possible to vary this proportion within even wider limits than in the case of calcium and silicon.

Equal portions of the magnesium-thermit and silicon-thermit, containing about 60 parts of magnesium and 40 parts of silicon as active metals, yield a good thermit reaction which evolves approximately as many calories as ordinary aluminium-thermit. However, these magnesium-silicon reactions have certain practical disadvantages which render them less suitable in practice than the aluminium-thermit reaction.

The production of magnesium-silicide, like that of calcium-silicide, has not yet been successfully carried out. Silicon acts on magnesia not as forcibly as on lime. A higher temperature is necessary, which results in the evaporation of magnesium from the alloy so that the final product contains a smaller quantity of magnesium in comparison with the content of calcium in my calcium-silicide.

It is similar with BaO and SrO . We succeeded in preparing a 40 per cent barium silicide at a comparatively low temperature, while the action of Si and SrO could not be established with certainty for reasons similar to the case of MgO .

Aluminium-Calcium.

In a third reaction aluminium is used together with calcium. In this case we have two elements, each of which gives a rapid reaction. It was, therefore, to be expected that under certain conditions the aluminium reaction can be strengthened by calcium. Experiments have confirmed this conclusion to some extent. The formation of an easily fusible calcium-aluminate slag is especially advantageous.

Calcium may be mixed with aluminium within very wide limits. Of course, too high a calcium content is to be avoided, while too small a calcium content has no effect.

An especially good proportion is a mixture of 40 parts of calcium thermit to 60 parts of aluminium thermit. The ratio of calcium to aluminium is about 53 to 47. The aluminate slag formed has the composition $3\text{CaO} - 2\text{Al}_2\text{O}_3$ and is very fluid. In the calorimeter this thermit shows an even higher heat effect than aluminium-thermit, namely, 880 calories.

With this calcium-aluminium thermit it is possible to carry out very nicely a number of metallic reductions. The reduction of chromium from chromic oxide succeeds very well. Compact reguli of chromium are obtained even from small quantities of pure chromic oxide, while with aluminium as reducing agent this is possible only if a certain amount of chromic acid is added to the chromic oxide.

The calcium-aluminium may be made either by melting the two elements together, if it is not preferred to use the calcium separately, or by electrolytic deposition of calcium on an aluminium cathode according to the patent of Poulenc. (See also United States Patent 875,666, application filed July 7, 1902, granted on Dec. 31, 1907.)

* * *

The question whether it is preferable to replace part of the aluminium in thermit by calcium is simply one of cost. Since 1 kg of aluminium combines with about the same quantity of oxygen, while 1 kg of calcium combines only with 0.4 kg of oxygen, the conditions are not very favorable. Metallic calcium must become considerably cheaper if there shall be any advantage in practice in replacing a small portion only of aluminium by calcium.

The use of magnesium was patented by me 10 years ago, but it has the practical disadvantage that magnesium cannot be made as cheaply as aluminium. For practical use in thermit this would be necessary since magnesium combines with less oxygen than aluminium.

The conditions are different with a mixture of silicon and magnesium or calcium. In this case the conditions are more favorable to magnesium since it combines with more oxygen than calcium. But calcium has the advantage that it can be made together with silicon at a relatively low expense. Nevertheless the practical result is not the same as with aluminium nor is the calorific effect the same, so that for the present most of these reactions are of more theoretical interest.

In each of these three reactions (calcium-silicon, magnesium-silicon and aluminium-calcium) the best results are obtained, if the composition is proportioned so that the slag becomes as fluid as possible.

For calcium-silicon, the most fluid calcium silicate slag is $4\text{CaO} - 3\text{SiO}_2$, with a melting point of 1425°C . (Boudouard, *Iron and Steel*, 1905, page 352). This corresponds to a thermit in which the active metals form an alloy of 67 per cent Ca and 33 per cent Si, or are mixed in this proportion.

A similar result is obtained with a magnesium-silicon thermit containing 60 per cent of Mg and 40 per cent of Si. The slag has the composition $7\text{MgO} - 4\text{SiO}_2$, with about the same melting point as $4\text{CaO} - 3\text{SiO}_2$.

A mixture of about equal parts of aluminium-thermit and

calcium-thermit (the proportion of calcium to aluminium being 63 to 67), gives a slag of the composition $2\text{CaO} \cdot \text{Al}_2\text{O}_5$, with a melting point of 1400°C .

Slightly lower is the melting point of the slag $3\text{CaO} \cdot 2\text{Al}_2\text{O}_5$, namely, 1395°C . This is formed from the reaction of a mixture of 40 per cent calcium-thermit and 60 per cent aluminium-thermit ($\text{Ca to Al} = 53$ to 47). See Boudouard, page 354.

It is certainly interesting to see that the constituent elements of the most abundant materials on earth, namely, aluminium, silicon and magnesium, yield the best thermit reactions, producing a high temperature and an extraordinary energy density, due to the high velocity of the reaction.

Dr. O. P. Watts and Mr. J. M. Breckenridge, at the last annual meeting of the American Electrochemical Society, have presented a paper in which they also deal with the possibilities of replacing aluminium in the aluminothermic reaction by other active metals, like calcium, magnesium and silicon. While in my researches I always had in view the technical applications, the investigation of Watts and Breckenridge is perhaps more of a scientific interest. I may say that until the publication of the report of this paper (this journal, June, 1908, page 237) I did not know of this investigation. This is, therefore, a case of two parallel independent researches leading to similar results. Messrs. Watts and Breckenridge refer in their paper to the patents which have been issued to me in the meanwhile.

Cold-Junction Temperature Corrections of Pt. Pt Rh and Pt. Pt Ir Thermo-Electric Pyrometers.

By CORNELIS OFFERHAUS AND ERNST H. FISCHER.

Thermocouples are extensively used in measuring high temperatures. The junction of two metals, of two alloys of different concentration or composition, or of a metal and an alloy is the seat of an e.m.f., the magnitude of which depends upon the temperature of the junction.

A practical arrangement for measuring temperatures by means of a thermocouple consists of connecting two wires of a different composition, as stated above, by twisting, or better soldering, them together, and placing the junction at the place the temperature of which is to be measured. This is called the hot-junction. The other ends (the so-called cold-junction) are connected by means of copper wire leads to a galvanometer of comparatively high resistance, so that the voltage drop in the couple will be small and the change in resistance of the couple, in heating it, negligible in comparison with the total resistance of the circuit. (See Fig. 1.)

The current which flows through the wires and which is measured by the galvanometer, is then a function of the difference of temperature between the hot and the cold junction. The temperature of the cold junction should not differ much from the temperature of the galvanometer; that is, the temperature of the cold circuit should be as uniform as possible.

Le Chatelier showed that but few metals are suitable for use as thermoelectric pyrometers and recommends as a result of an extensive investigation a couple of Pt and an alloy of Pt with 10 per cent Rh. Heraeus, in Hanau a/M, have such couples of very homogeneous wires on the market, and Siemens & Halske have under the millivolt scale of their galvanometer, especially constructed for the purpose, a temperature scale to be used with such a couple.

Besides Pt. Pt Rh couples with 10 per cent Rh, there are on the market couples of other concentrations, and, although Pt Rh-alloys have certain advantages over Pt. Ir alloys, Pt. Pt Ir couples are used.

Before using a couple it must be calibrated. In doing this the cold junction is kept at a constant temperature of 0°C . The hot junction is placed in the vapors of chemically pure substances of known boiling points and in molten chemically pure substances of known melting points and the constant e.m.f. produced is read. A calibration curve is plotted with the e.m.f. as abscissa and the temperature as ordinate.

The couple may also be calibrated by comparing it with a standard couple, which has already been calibrated as described above. Comparison with a gas-thermometer is not practical.

For high temperatures the calibration curve of Pt. Pt Rh and Pt. Pt Ir. couples deviates but slightly from a straight line and is well represented above 250°C by the following logarithmic formula derived by Holman.

$$\log e = a \log t + b$$

in which e is the e.m.f. (preferably in microvolts); t , the temperature, to be measured in degrees C , and a and b are two constant factors, depending mainly upon the composition of the couples. For the lower range of temperatures, portions of the curve are well expressed by a parabolic formula.

In using the calibrated couple to measure temperatures, the temperature of the cold junction may be kept at 0°C , e. g., the temperature at which it was calibrated, thus avoiding a cold-junction correction. The temperature which corresponds to the millivolts read is then the true temperature.

It is, however, easier and theoretically more correct to keep the temperature of the cold junction as nearly the temperature of the room as possible. This is accomplished by placing it in a waterbath of sufficient size to maintain more or less a constant temperature.

In using this arrangement, before connecting the galvanometer in the circuit, its needle may be placed at the millivolt corresponding to the temperature of the cold junction as read at the thermometer placed in the waterbath; in this way subsequent correction for the temperature of the cold junction is avoided.

The temperature of the room, and that of the cold junction, may change during a given operation and it will, therefore, be more correct to start with the needle at zero and to correct for the temperature of the cold junction, the two readings, e. g., galvanometer and thermometer reading, being taken simultaneously.

The current indicated by our instrument is a measure of the difference in temperature between the hot and the cold junctions. The true temperature of the hot junction is, therefore, if we start with the needle at zero (the cold junction having the temperature of the room), not the temperature which corresponds to the millivolt reading, but the true temperature is found by adding the number of millivolts, which corresponds to the temperature of the cold junction, to the millivolt reading. That this way of operating is correct is shown by Table I, which contains experimental data and which is self-explanatory.

Adding the temperature of the cold junction to the temperature corresponding to the millivolt reading, or to the temperature read directly from the temperature scale, is not permissible, unless we multiply this temperature by a certain correction-factor which is smaller than unity. R. Vogel (*Zeit. f. Anorg. Chem.*, 1905, 45) seems to have been the first who calculated and applied correction factors for the temperature of the cold junction in reading in this way. The correction factor comes in because the relation of e.m.f. and the temperature is not a straight line.

This relation, and the correction factor in consequence, changes with the composition of the couple, and the correction factor for each couple changes furthermore with the temperature of its hot junction and also with the temperature of its cold junction. It should be pointed out that the correction factors indicated by Vogel are calculated from an Heraeus Pt. Pt Rh (10 per cent) couple and a cold junction of about 50°C . and that they hold good only for this couple.

As the last method for reading with or without applying a correction factor for the temperature of the cold junction is in general use, it will be of interest to show just how much this correction factor for the temperature of the cold junction is influenced by the composition of the couple and how it changes for each couple with the temperature of the hot and cold junctions.

For this purpose five different couples, all of which are on

the market, and sold as thermoelectric pyrometers, were calibrated. The couple marked No. 1 is the Heraeus Pt-Pt Rh (10 per cent) couple; No. 2 is a couple from Belais & Cohn, New York, and sold as Pt-Pt Ir (3 per cent). No. 3 is a Pt-Pt Rh couple from the Cambridge Scientific Instrument Co., Ltd., England; No. 4 is a couple from Belais & Cohn, New York, and sold as Pt-Pt Ir (10 per cent); No. 5 is a Pt-Pt Ir couple from the Cambridge Scientific Instrument Co., Ltd., England.

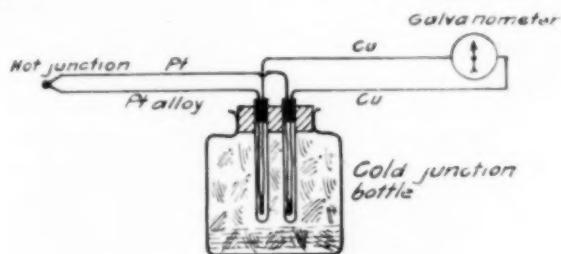


FIG. 1.—CONNECTIONS OF PYROMETER.

The cold junction was kept at a constant temperature (0° C.) and the boiling points of water, naphthalene (218° C.), sulphur (445° C.), and the solidification points of pure antimony (631° C.) and copper (1084° C.) were taken as constant temperatures. The arrangement described before (Cu—Pt—Pt. alloy—Cu), and shown by Fig. 1, was used.

In this arrangement there is no true cold junction, but a cold circuit. An arrangement with a true cold junction (Cu—Pt—Pt. alloy—Pt.—Cu) for which one more Pt-wire is required and which is shown in Fig. 2, gives exactly the same figures as were found repeatedly by experiment (the temperature of the cold junction was 0° C.).

It is practically sufficient that the temperature of the connections of the Pt- and Pt-alloy wire with the copper leads be uniform, although it is better that the temperature of the entire cold-circuit be uniform. In using ice in the bath for the cold junction, the temperature of the cold junction was found to be not 0° C. but 2° C., and so in order to have the cold junction at 0° C. the tubes of the cold-junction bottle (see Fig. 1) were filled with ice.

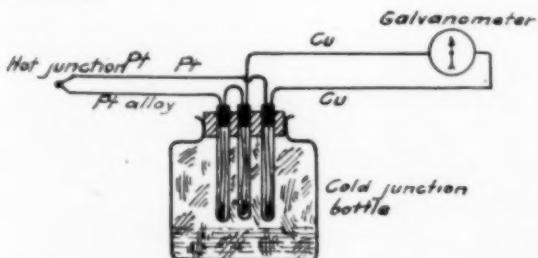


FIG. 2.—CONNECTIONS OF PYROMETER.

In taking the cooling curve of antimony it is necessary to stir it a short time before and during the solidification. Antimony shows, as is known, the phenomena of undercooling, and if considerable undercooling takes place, the temperature will not quite reach the melting point. In taking cooling curves of copper, pure hydrogen-cooled shot-copper in a graphite crucible was used; the metal was kept well covered with charcoal. In order to get the true sharp solidification point we recommend poling the melted copper as well with small sticks of wood. By doing this, very constant points were obtained, generally somewhat higher than when omitting this operation.

From the data obtained curves were plotted, which are shown in Fig. 3. Logarithmical formulae were calculated, which were based on the constants of sulphur and copper, found by experiment. These formulae are used from 100° C. up. Between 0° C. and 100° C. a parabolic formula of two terms was derived and used in subsequent calculations. It was found that the

functions applied between these ranges agreed best with the relation found by experiment. They contain few terms, making the work of computation a minimum. Table II gives the formulae found for the different couples, and Table III shows temperatures calculated with the logarithmic formula and the true temperatures for couple No. 2 and No. 4.

Table IV contains the correction factors for the five couples under discussion, calculated with these formulae for a cold-junction temperature of 0° C., e. g., a temperature near 0° C., and different temperatures of the hot junction from 100° up to 1100° C. in intervals of 100° C.

Table V contains the correction factor for one of these couples (No. 2) calculated for the same temperature of the hot junction as before, but a variable temperature of the cold junction.

A concrete example may show the method used in calculating. In Table IV it is seen that the correction factor for a temperature of the cold junction near 0° C. in using couple No. 2 is 0.55 for a hot junction of 700° C.

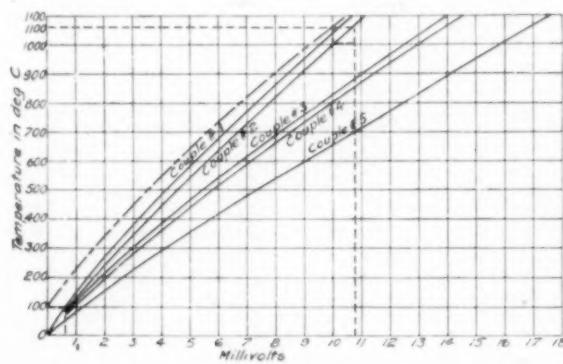


FIG. 3.—CURVES OF RESULTS.

The lower part of the calibration curve of this couple is well represented by the formula:

$$E = 5.9115 + 0.0178 t^2$$

The tangent is: $\frac{dE}{dt} = 5.9115 + 0.0178 t = 5.9115$ for $t = 0^{\circ}$ C.

The upper part of the same curve is well represented by the formula:

$$\log e = 1.1116 \log t + 0.6657$$

$$\text{or } \log e - \log x = 1.1116 \log t$$

$$\text{hence } e = x \times t^{1.1116}$$

hence: $\frac{de}{dt} = 1.1116 \times x \times t^{0.1116} = 10.512$ for $t = 700^{\circ}$ C.

The ratio of the tangent at different temperatures to the tangent at 0° C. gives their correction factors if the temperature of the cold junction is near 0° C. The correction factor for the temperature of the hot junction of 700° C., the cold junction being near 0° C., is, therefore:

$$\frac{5.9115}{10.512} = 0.55 \quad (28).$$

The couples are calibrated and the formulas derived with a cold junction of 0° C. Only the correction factors for temperatures of the cold junction which are near 0° C. can, therefore, be calculated in this way. The factors for other temperatures of the cold junction are calculated as follows:

To find the correction factor of couple No. 2, for a hot junction of 1000° C., the cold junction being 100° C., insert $t = 1000$ in the logarithmic formula and solve for e (see also Fig. 3).

$$\log e = 1.1116 \log 1000 + 0.6657$$

$$e = 10012.$$

Add 760 microvolts, which correspond to 100° C., insert the sum = 10772 microvolts in the same equation and solve for t :

$$\log 10772 = 1.116 \log t + 0.6657$$

$$t = 1068.1.$$

The correction factor is then:

$$\frac{68.1}{100} = 0.68 \quad (1.).$$

The correction factor can also be found graphically. In mov-

may be cut down by putting in outside resistance. The resistance necessary can be calculated from the formula:

$$E_1 (w + w_1) = E w$$

in which E = the voltage reading without outside resistance,
 E_1 = the voltage reading with outside resistance,
 w = resistance of the instrument,
 w_1 = the outside resistance.

The resistance once fixed and the calibration without resistance made, points of the new calibration curve can be calculated with the help of the same formula, e. g., it is not necessary to recalibrate. The high temperatures in question are found by extrapolation.

Electrodeposition of Nickel.

Dr. EDWARD F. KERN and Mr. FRANCIS G. FABIAN have published in the July issue of the *School of Mines Quarterly* an extensive report on an investigation carried out at Columbia University on the electrolytic deposition of nickel.

The authors first give abstracts from literature on the electrodeposition of nickel and sum up the results of former work as follows:

The electrolyte generally used for electroplating is a solution of nickel-ammonium sulphate, which may be neutral, or else slightly acid with a weak acid such as boric, phosphoric, benzoic, acetic, tannic, tartaric or citric; it may also contain alkali salts of these acids. The acid is added for the purpose of dissolving basic salts of nickel, which are the result of oxidation. An excess of acid causes evolution of hydrogen which produces spongy or non-adherent deposits.

Electrolytes containing nickel-ammonium phosphate are used to less extent than those containing nickel-ammonium sulphate.

In exceptional cases, electrolytes containing nickel chloride and nickel-potassium cyanide have been used.

The presence of boric acid in nickel electrolytes not only keeps the solution clear, but also causes the formation of a smoother and less brittle deposit than when not present. The amount used runs from 1.5 to 30 grams H_3BO_3 per 100 c.c. solution.

Nickel deposits formed in nickel-ammonium sulphate electrolytes are harder, smoother and more durable than those from chloride electrolytes.

The addition of 5 to 10 grams of sodium chloride per 100 c.c. of nickel-ammonium sulphate electrolyte reduces the e.m.f., and also causes the deposit to form more reguline, more adherent and tougher, and the anode to dissolve more uniformly.

Pure nickel anodes are less readily dissolved than those which contain iron, copper, tin, etc., unless the electrolyte contains a chloride.

Rolled sheet anodes are less readily dissolved and require a higher e.m.f. than cast anodes.

Rough cast anodes require less e.m.f. and are more uniformly dissolved than smooth, polished cast anodes, or sheet nickel anodes.

The solutions which are used for recovering nickel from nickel-copper mattes, or alloys, are either dilute sulphuric acid or dilute hydrochloric acid. The copper in either solution is reduced below 1 per cent by electrolysis and finally completely removed chemically by cementation on metallic nickel, or else by hydrogen sulphide which is afterwards expelled. The purified solution is rendered alkaline, filtered to remove precipitates and the nickel recovered by electrolysis in suitable cells, using a lead anode for the sulphate solution and a graphite anode for the chloride solution.

The refining of nickel is said to be accomplished in electrolytes of nickel-potassium cyanide, or else of neutral nickel-sodium chloride. The sulphate electrolytes are not so satisfactory as these, as the deposits from sulphate electrolytes contain some sulphur.

There is a difference of opinion as to the cause of solid, adherent deposits of nickel; some electrometallurgists claim that the

most satisfactory deposits are from alkaline electrolytes, whereas others say that the electrolyte must be acid. The general opinion, however, is that non-adherent deposits are due to: the electrolyte being too acid, the temperature of electrolyte being too low, or else the cathode is not clean. Pulverulent deposits are due to: too high a current density, too high an e.m.f., and too acid electrolyte.

The formation of insoluble basic salts is prevented by acidifying the electrolyte with a weak acid, such as boric, perchloric, perbromic, or an organic acid, or else with a slight amount of sulphuric or hydrochloric acid.

Conditions which favor solid adherent deposits of nickel are: slightly acid electrolyte, to prevent basic salts; pure electrolyte; gas-free electrolyte; temperature between 40° and 65° C.; constant current density; low e.m.f.; efficient circulation; clean cathode; and concentrated electrolyte.

Concentrated electrolytes, especially those consisting of very soluble nickel salts, give the most satisfactory deposits, other conditions being equally favorable.

The tendency of nickel deposits to curl is greatest with high current density, said to be due to formation of nickel hydride, which is the result of greater liberation of hydrogen with high current density and high e.m.f.

The presence of nitric acid in a nickel electrolyte prevents the formation of solid deposits.

The idea which is apt to prevail after one has reviewed the literature on the electrolytic refining of nickel is that numerous processes have been suggested, devised and published, but that only a few have gained any degree of technical success. Even the more recent processes possess such disadvantages as large and expensive plants, complex apparatus, and a number of involved operations, which must necessarily entail losses, all of which are quite serious objections."

In passing over to an account of their own researches, Messrs. Kern and Fabian make the general statement that "the conductivity of an electrolyte varies directly as the weight of salt in solution, and the more concentrated the electrolyte, the more satisfactory the deposit. As examples may be cited: lead fluosilicate, silver nitrate, gold chloride, copper fluosilicate, nickel chloride, antimony fluoride, and iron chloride, all of which yield more satisfactory deposits than electrolytes of other salts of the respective metals. Another great advantage gained by using the more soluble salt is lessening the inconvenience due to salts crystallizing and collecting between contacts, and also forming on the electrodes, especially the anode, all of which offers high resistance to the passage of the current." So, before deciding on what salts they would use in the investigation, they looked up the solubilities of the more soluble salts of nickel, which are given in the following table:

Table of Solubilities of Nickel Salts.

Nickel bromide: $NiBr_2$; soluble in water, alcohol and ether.

Nickel chloride: $NiCl_2 \cdot 6H_2O$; easily soluble in water, alcohol and ether. 100 c.c. saturated water solution at 20° C. contains 39 grs. $NiCl_2$. 100 c.c. saturated water solution at 40° C. contains 42 grs. $NiCl_2$.

Nickel iodine: NiI_2 ; easily soluble in water. 100 c.c. saturated solution at 20° C. contains 60 grs. NiI_2 . 100 c.c. saturated solution at 40° C. contains 64 grs. NiI_2 .

Nickel cyanide: $Ni(CN)_2$; insoluble in water. Nickel-potassium cyanide $Ni(CN)_2 \cdot (KCN)_2$; easily soluble in water, more soluble if KCN is present.

Nickel dithionate: $NiS_2O_6 \cdot 6H_2O$; soluble in 0.897 part water at 12° C.

Nickel-ammonium dithionate: $2NiS_2O_6 \cdot 9(NH_4)_2S_2O_8 \cdot 16.5H_2O$; soluble in water and in an excess of ammonia.

Nickel fluosilicate: $NiSiF_6 \cdot 6H_2O$; easily soluble in water.

Nickel thiosulphate: $NiS_2O_6 \cdot 6H_2O$; permanent, soluble in water.

Nickel sulphate: $NiSO_4 \cdot 7H_2O$; soluble in three parts water at 20° C. Soluble in two parts water at 50° C.

Nickel-ammonium sulphate: $NiSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$; soluble

in 12 parts water at 20° C. Soluble in 5 parts water at 50° C.

Nickel-sodium sulphate: $\text{NiSO}_4 \cdot \text{Na}_2\text{SO}_4 \cdot 4\text{H}_2\text{O}$; soluble in 3 parts water at 20° C.

Nickel-potassium sulphate: $\text{NiSO}_4 \cdot \text{K}_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$; soluble in 9 parts water at 20° C.

Nickel phosphates: insoluble in water, soluble in dilute ammonia, and in dilute phosphoric acid.

From this list Messrs. Kern and Fabian selected the following electrolytes to be investigated: nickel dithionate, nickel fluosilicate, nickel chloride, and nickel sulphate, because of their higher solubility and their cheapness of preparation.

While for the full amount of the experiments of the authors reference must be had to the original paper, we will here sum up only the chief results of the investigation. The average data of the different runs made will be seen from the following table:

Composition of the Electrolytes.	NiCl ₂ Electrolyte.			NiSO ₄ Electrolyte.			NiSiF ₆ Electrolyte.		
	Temperature, °C.	C. D. amperes per sq. ft.	Time of run, minutes.	Average e.m.f. in volts.	Cathode current efficiency.	Average e.m.f. in volts.	Cathode current efficiency.	Average e.m.f. in volts.	Cathode current efficiency.
8% nickel & half molecular equivalent of free acid.	20 10	180	0.49	3.20 "	0.89	0.86 12%	0.96	0.78 "	
	40 10	180	0.36	1.25 "	0.65	0.62 12%	0.78	1.64 "	
	60 10	180	0.21	1.01 "	0.42	0.39 "	0.61	1.80 "	
8% nickel & 1/10 the molecular equivalent of free acid,	20 10	255	0.73	62.6 "	0.91	1.50 "	0.82	2.20 "	
	40 10	255	0.52	79.0 "	0.78	1.60 "	0.83	4.90 "	
	60 10	255	0.35	71.0 "	0.51	1.50 "	0.61	4.80 "	
8% nickel & 1/20 the molecular equivalent of free acid,	20 12	180	0.86	67.2 "	0.97	0.0 "	1.02	7.8 "	
	40 12	180	0.53	75.7 "	0.79	0.7 "	0.90	7.1 "	
	60 12	180	0.44	86.7 "	0.61	2.8 "	0.82	8.5 "	
Neutral solutions containing 8% nickel.	20 10	255	0.78	96.6 "	1.50	102.2 "	1.05	92.1 "	
	40 10	255	0.59	99.4 "	1.35	106.9 "	0.94	92.4 "	
	60 10	255	0.44	99.2 "	0.88	101.1 "	0.73	89.8 "	
Neutral solutions containing 8% nickel.	20 20	480	1.06	91.2 "	3.45	1.45	96.8 "		
	40 20	480	0.73	94.7 "	2.30	1.24	100.0 "		
	60 20	480	0.64	88.3 "	1.40	1.01	90.3 "		
Neutral solutions containing 8% nickel and a half molecular equivalent of sodium salt.	20 20	180	1.02	90.2 "	3.12	10.2 "			
	60 60	180	0.58	99.7 "	0.96	99.8 "			

In all of the experiments, cast nickel anodes, containing 92 per cent Ni, 5 per cent Fe, carbon and trace of Cu were used. The cathodes were sheet nickel placed one inch from the anodes.

Nickel dithionate is not suitable for nickel electrolytes, as it is decomposed with the separation of sulphur. The e.m.f. required for an electrolyte containing 3 per cent nickel, and at room temperature, was 2.7 volts.

The presence of free acid in nickel chloride, nickel sulphate and nickel fluosilicate electrolytes caused very low cathode efficiency, whereas the anode efficiency was in most cases over 95 per cent. By continued electrolysis the free acid was neutralized and the cathode efficiency increased.

The electrolysis of neutral chloride and fluosilicate solutions with current densities of 10 and 20 amperes per square foot gave very satisfactory deposits, and high current efficiencies. Neutral sulphate solutions were unsatisfactory, as precipitates of insoluble basic salts formed and intermixed with the deposited nickel.

Heating the chloride and the fluosilicate electrolytes decreased the e.m.f., increased the current efficiencies and improved the deposition. The most satisfactory temperature was about 50° C.

During electrolysis of nickel fluosilicate solutions, a small amount of gelatinous silica separated and collected on the bottom of the cells. Heating of these solutions above 75° C. also caused the separation of silica, but very slowly.

A small amount of basic salts separated during electrolysis from the neutral chloride electrolytes, but did not interfere with the deposition. The presence of a small amount of free acid prevented their formation.

On Methods of Obtaining Cooling Curves

BY G. K. BURGESS.

CONTENTS.

Methods of Thermal Analysis.

Use of the Thermocouple.

Methods of Recording.

Temperature—Time Curves.

I. θ vs t

Photographic Recorders.

Autographic Recorders.

II. θ vs t , θ' vs t

Differential Curves.

III. θ vs t , $\theta - \theta'$ vs t

Use of a Neutral Body.

IV. θ vs $\theta - \theta'$

IVa. θ vs $\theta - \theta'/\Delta\theta$

Direct and Inverse Rate Curves.

V. θ vs $d\theta/dt$

VI. θ vs $dt/d\theta$

Rapid Cooling.

Characteristics of Cooling Curves.

The rôle of thermal analysis in many metallurgical and chemical problems, involving in many instances the constitution and behavior of very complex substances, is of increasing importance; and great advances are being made in our knowledge of the properties of many alloys, minerals and chemical compounds at high temperatures by means of the pyrometer.

Any internal change in the physical or chemical nature of a substance usually alters many of its physical properties, as, for example, its magnetic and thermoelectric behavior, electrical resistance, specific heat, density and microscopic structure. A large internal change at a definite temperature or within a small range of temperature—in other words, "a transformation"—will cause sudden or very rapid changes in some or all of these physical properties, and several of them may be used with advantage in the detection and study of such transformations. In this paper, however, we shall confine ourselves to the consideration of such changes as may be detected, measured and recorded by thermometric means.

METHODS OF THERMAL ANALYSIS.

All methods of thermal analysis are based upon the principle that chemical and physical transformations within a substance are, in general, accompanied by an evolution or absorption of heat. The detection of the temperature and the measurement of the extent of these transformations, and in many cases their interpretation, may be carried out by taking the cooling curve of the substance, which in its simplest form consists in plotting the temperature of the cooling substance against the time.

It is evident that the heating curve of a substance may also be taken to find its characteristics, and this is sometimes done, but in general uniform results are obtained more easily by taking the cooling curve, mainly on account of the greater experimental difficulties in maintaining an uniform rate of heating in the containing furnace. In some problems it is desirable to have both curves, while occasionally, as in transformations involving loss of water or crystallization or of constitution, the heating curves alone are of significance. The same apparatus will evidently serve for both.

The cooling curve, however exactly taken, will, of course, give no indication of those transformations for which there is no evolution or absorption of heat. If the cooling is at constant pressure, as we shall assume in all of what follows, the absence of a transformation—physical or chemical—may be assumed only when both the energy and the volume changes are zero.

The detection of changes in volume, unaccompanied by changes in internal energy, may be effected by the use of an apparatus measuring linear expansion, such as the recording differential dilatometer of Sahmen and Tammann.¹ These cases

¹ Sahmen und Tammann: Über das Auffinden von Umwandlungspunkten mit einem selbst-registrierenden Dilatographen. *Ann. d. Phys.*, 10, p. 879-896; 1903.

are exceptional, however, and we shall not consider them further.

There have been developed a considerable number of methods for obtaining cooling curves which are adapted to the study of recalcence points in steels as well as to the investigation of the composition and properties of alloys and chemical compounds. There has as yet been no general discussion² of the different methods nor of their availability for special problems and it may, therefore, be of some interest to have at hand an outline of the principles of the methods that may be used in obtaining cooling curves as well as a brief mention of the various types of apparatus available, with a discussion of their advantages and limitations.

The methods may be classified in various ways; thus we have to distinguish between those adapted for slow cooling, which is the case most commonly met with, and for very rapid cooling, as in quenching steels; those methods which require an auxiliary body possessing no thermal transformations on cooling, as compared with those requiring only the substance studied; and, finally, we may have, on the one hand, methods involving the time, and, on the other hand, those in which the time may be eliminated. In this paper we have considered in detail only such methods as are adapted for slow cooling and have classified them in terms of the forms of the curves representing the experimental data.

Many operations which can be carried out in the laboratory cannot be applied conveniently in industrial works, so that it will be necessary also to distinguish the various types of apparatus as regards their adaptability either for purely scientific researches or for industrial needs. For the latter, especially, it is very desirable to make all operations as automatic as possible, so that the different methods of autographic and photographic recording should be considered.

Again, we shall have occasion to point out those methods which are the most advantageous to use when very minute quantities of heat or differences in temperature are to be detected, as, for example, the secondary breaks in the cooling curves of many alloys and of numerous compounds and mixtures. In such cases it becomes necessary to use methods of the highest possible sensitiveness, which usually necessitates the discarding of autographic and photographic recording.

We shall mention those methods which are suitable for taking cooling curves in the range of temperatures up to 1500° C., but much of what is said will apply also to higher temperatures if proper precautions be taken to eliminate the effects upon the measuring apparatus of the electrical conductivity of the materials and contents of the furnace. Although several methods of measuring temperature may be used over most of the range indicated, such as the change of electrical resistance of platinum with temperature and the various optical and radiation pyrometers, we shall confine ourselves to the thermo-electric pyrometer made of the platinum metals as being on the whole the most generally suitable over this range for this kind of work, although undoubtedly particular problems may occur in which the use of some other type of pyrometer is preferable.

Use of the Thermocouple.—It may be recalled that the thermocouple possesses most of the desirable attributes of a temperature indicator. With its insignificant volume it may be introduced into a very small space, and so be used with small samples, and it takes up the temperature of the sample with great promptness. When made of the platinum metals, it is very durable and retains the constancy of its indications in a most satisfactory way, even when subjected to contaminating atmospheres, and after deterioration it may usually be restored to its former condition by glowing.

Temperatures may be obtained by means of a simple form of

² A paper by W. Rosenhain, on "Observations on Recalcence Curves," was read before the London Physical Society, January 24, 1908, an abstract of which indicates he has compared the merits of the "Inverse Rate" and "Differential Methods."

The Differential Method has also been studied in detail by Portevin, Notes sur l'Emploi du Galvanomètre Différentiel, *Rev. de Métallurgie*, 5, p. 295; 1908.

galvanometer without any accessories. Such a galvanometer, it is true, indicates electromotive forces, while in general the temperature of a thermojunction is not strictly proportional to the electromotive force generated by it, although such a linear relation, which it is desirable to realize in order to simplify the interpretation of the indications of some types of recording instruments, holds very nearly in the case of the platinum-iridium couple of the composition Pt, 90 Pt—10 Ir.

The following table shows the e.m.f. temperature relation and the e.m.f. in microvolts per degree centigrade (de/dT) for couples composed of a wire of pure platinum joined to one of approximate composition: 90 Pt—10 Rh, 90 Pt—10 Ir, and pure Ni, respectively.

Temp. Cent.	Pt, 90 Pt—10 Rh		Pt, 90 Pt—10 Ir		Pt, Ni	
	Microvolts	e.m.f. de/dT	Microvolts	e.m.f. de/dT	Microvolts	e.m.f. de/dT
300	2,290	9.0	4,080	15.9	7,940	11.8
500	4,160	9.7	7,300	16.7	10,510	14.4
700	6,170	10.45	10,720	17.5	13,670	17.1
900	8,340	11.2	14,300	18.3	17,400	19.7
1,100	10,630	11.9	18,030	19.1	21,640	22.4
1,300	13,070	12.6	21,940	19.9	26,300	25.0
1,500	15,600	13.38	26,010	20.7

It will be seen that the platinum-iridium couple is nearly twice as sensitive as the platinum-rhodium couple besides having a more nearly linear e.m.f.-temperature curve. The advantages are in part offset, however, by the fact that the iridium couple deteriorates more rapidly and is less constant in its indications.

The platinum-nickel couple, although very sensitive, is less reliable than the others, and the Ni wire soon becomes brittle and breaks. Moreover, the effect of the nickel recalcence point (about 375° C.) has some influence on readings taken in its neighborhood.

There are other thermojunctions, made of alloys of the more refractory baser metals, which are much more sensitive than the above and which may be suitable over particular ranges. These couples are usually constructed of wire of considerable diameter and are, therefore, not adapted for work with small samples. For exact work one should make sure of their constancy of indication over the temperature range to be studied.

A more robust and less sensitive indicating instrument may evidently be used with this type of thermocouple, although recently pivot instruments, suitable for use with the platinum couples, have been constructed by Paul, of London, and by the Cambridge Scientific Instrument Company.

Methods of Recording.—Before describing the various methods that have been suggested for the taking of cooling curves, it may be well to consider the ways in which the observations may be recorded. Either the observer may himself read and record the indications of the instruments and discuss the data so obtained, either analytically or graphically; or he may use, if the method and desired precision permit, either an autographic or photographic self-registering instrument, when it may or may not be necessary to make further reductions, depending upon the method used and the interpretations sought.

It is evidently of great advantage to use self-recording apparatus when possible and it then becomes necessary to choose between the photographic type and the autographic.³

The latter possesses the advantage that the experimenter may watch any part of the record and can, therefore, control the operation and at any moment vary the conditions affecting the experiment, whereas with a photographic recording apparatus, as usually constructed, the observer does not know whether or not the experiment is progressing properly until it is finished and he has developed the sensitive plate. The manipulation by the photographic method is usually also more delicate and time-consuming and the adjustment less sure, and the record often requires further graphical interpretation.

The autographic method is in general not adapted for interpreting phenomena taking place within an interval of a few seconds, so that for very rapid cooling it is necessary to employ the photographic method. It is possible to construct the photo-

³ The term autographic is here used to designate an instrument which is self recording by any other than photographic means.

graphic recorder so as to obtain a very considerable range of speeds with the same apparatus, while it is difficult and costly to construct an autographic recorder having more than two speeds.

* * *

Temperature-Time Curves.

I. θ vs t .—The simplest method of obtaining a cooling curve is to take simultaneous measurements of the temperature of the cooling substance and of the time, from which a plot

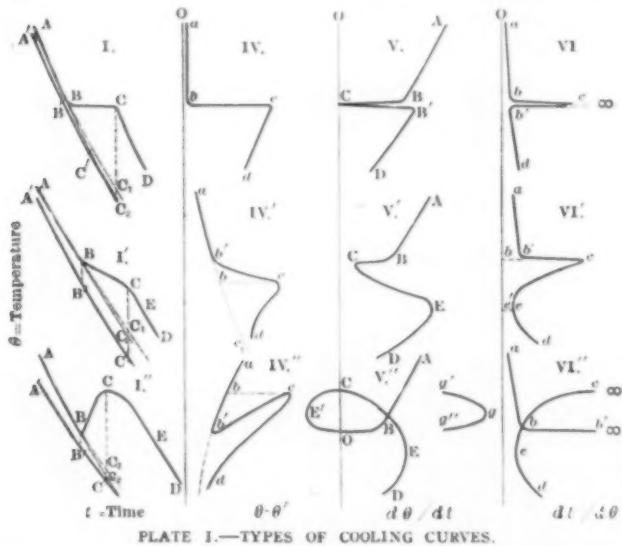


PLATE I.—TYPES OF COOLING CURVES.

may be made showing the variation of temperature with time. (See Plate I, Fig. 1.)

The most obvious defect of this method is that it will not distinguish between phenomena proper to the substance studied and those due to outside conditions, such as accidental variations in the rate of cooling of the furnace due to air draughts and like causes. Again, where measurements over a considerable range of temperature are to be taken continuously, it becomes impracticable without elaborate experimental arrangements to combine great sensibility with this great range, so that the experimenter is in general forced to choose between great sensibility over a small temperature range or a relatively small sensibility over a large range; and this is especially true if it is desired to record the data automatically.

This method was naturally the first used⁴ and it is to-day perhaps the most common one for taking cooling curves in both metallurgical and chemical laboratories. In its most elementary form it requires a minimum of apparatus—a thermocouple and an indicating galvanometer. Any desired sensibility and range may be had by substituting for the direct-reading galvanometer a potentiometer and a sensitive galvanometer. With this arrangement it is advantageous, when rapidity of observation is an object, to measure the last increment of temperature in terms of the galvanometer deflection rather than try to balance the potentiometer exactly while the temperature is changing.

It is possible in this way to take readings as often as every five seconds with a properly devised, set-up and quick-period galvanometer.⁵ A precision of 0.1°C . at 1000°C . may be attained. Independently of the method of measurement used, the certainty of the detection of slight transformations may usually be increased by increasing the size of the sample under observation, thus making available larger quantities of heat.

The constant attention of the observer is, of course, required for either of the above systems of measurement. There have been devised, however, many kinds of self-recording apparatus for using this method, the earlier forms being photographic, while many of the later ones are autographic.

⁴ Frankenheim: *Pogg. Ann. der Physik*, 37, 38 (1836-1837).

⁵ See W. P. White, Potentiometer Installation, *Phys. Rev.*, 25, 334; 1907.

Photographic Recorders.—Among the earliest photographic recorders we may mention the apparatus of Roberts-Austen⁶ (Fig. 1), in which the photographic plate *P* was given a vertical motion, either by clockwork, or, in order to secure maximum sensibility for several rates of cooling, by means of buoying the plate on water whose rate of flow could be regulated. The

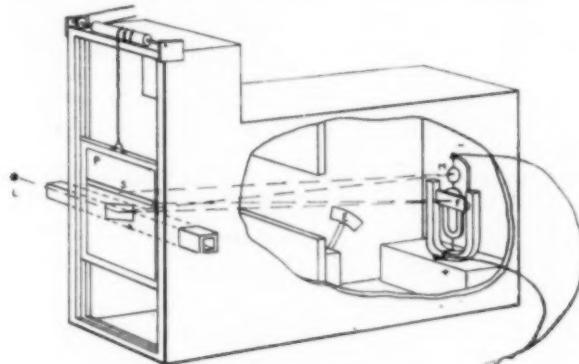


FIG. 1.—ROBERTS-AUSTEN RECORDER.

vertical motion of the plate then gave the time, while the deflection of the galvanometer gave the corresponding temperature, and a beam of light, from the source *L*, reflected from the galvanometer mirror *M*, and incident on the plate, after passing through a fine slit *s* placed horizontally before the moving plate, gave directly on the latter the time-temperature curve.

Light reflected from a fixed mirror *F*, and interrupted at equal intervals by a pendulum *E*, gave a fixed zero line as well as a measure of regularity of the motion of the plate. It was the practice later,⁷ when taking measurements over short temperature ranges, to increase the sensibility by balancing the greater part of the e.m.f. of the thermocouple with an auxiliary measured e.m.f., and giving the galvanometer the maximum sensibility that would keep its deflections on the plate.

In the apparatus used by Charpy,⁸ or in its very elaborate form as constructed by Toepper, of Potsdam, for Kurnakow⁹ the vertically moving plate is replaced by a rotating cylinder wound with the sensitized paper on which the deflections of the galvanometer are registered. This form of recorder had also been used and discarded by Roberts-Austen.

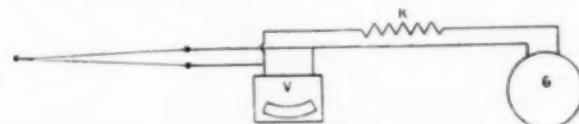


FIG. 2.—SCHMIDT DEVICE.

Kurnakow's apparatus, which must be placed in a dark room, is furnished with an auxiliary telescope and scale system using red light, so that the experiment may be controlled during the taking of a record. As constructed, five speeds may be given to the cylinder; and there is provided an e.m.f. compensating system for maintaining the maximum sensibility over a series of temperature ranges.

There is another device, used by C. L. A. Schmidt,¹⁰ by which the experiment may be watched while a photographic record of a cooling curve is being taken. It consists in shunting the sensitive photo-recording galvanometer *G* (Fig. 2) in series with a high resistance *R* across a direct-reading millivoltmeter *V*. If the resistance of *R* + *G* is great compared with that of *V*, the readings of the millivoltmeter will not be altered appreciably

⁶ Proc. Royal Society, 49, p. 347; 1891. *Nature*, 45, p. 534; 1892. First Report of the Alloys Research Committee in Proc. Inst. Mech. Engrs., 1891.

⁷ G. Charpy, *Bull. de la Soc. pour l'Encouragement*, 10, p. 666; 1895. Fourth Report of the Alloys Research Committee, Proc. Inst. Mech. Engrs., 1897. A. Stansfield, *Phil. Mag.*, 46, p. 59; 1898.

⁸ N. S. Kurnakow, *Zeitsch. f. Anorg. Chemie*, 42, p. 184; 1904.

⁹ C. L. A. Schmidt, *Chem. Eng.*, 6, p. 80; 1907.

by this operation. Schmidt moves the photographic plate, mounted as in the apparatus of Roberts-Austen, by means of a screw driven by a small motor. In this way any desired speed may be given to the plate.

In practice it has been found difficult to realize conveniently a sufficiently steady motion of the plate in the Roberts-Austen system of recording, and attempts have been made to devise methods in which the photographic plate remains fixed in position. This has been successfully accomplished by Saladin, whose apparatus (Fig. 8) has been modified by Wologdine¹¹ to give the temperature-time curve by removing the prism M and substituting for the second galvanometer G_2 a plane mirror turning about an horizontal axis. This mirror may be controlled by an hydraulic system as in Roberts-Austen's apparatus, or by clock-work as in the model constructed by Pellin, of Paris. The deflection of the galvanometer G_1 gives to the beam of light an horizontal motion over the plate proportional to the temperature, while the vertical motion of the beam of light is given by the mirror turning at a uniform rate and is therefore approximately proportional to the time as registered on a flat plate.

Autographic Recorders.—To obtain a satisfactory autographic or pen record without sacrifice of sensibility of the galvanometer it is necessary to eliminate the friction of the pen or stylus upon the paper. This has been accomplished by the use of mechanisms which cause the pen or stylus at the end of the galvanometer boom to make only momentary contact with the moving paper.¹²

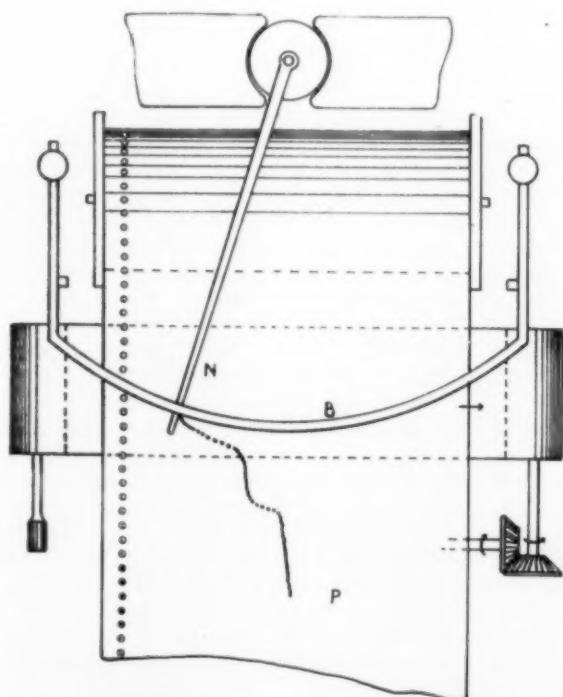


FIG. 3.—SIEMENS & HALSKE INSTRUMENT.

In the Siemens & Halske¹³ form of instrument, Fig. 3, the paper P is driven forward by the same clock-work that controls the pressing down by means of the arm B of the stylus N which imprints dots periodically on the paper by means of a typewriter ribbon running across and beneath the record sheet. This system permits of taking a record continuously over very long periods of time. In most of the other recorders the paper is wound upon a drum, and various devices are used to obtain

¹¹ S. Wologdine, *Rev. de Métallurgie*, 4, p. 552; 1907.

¹² There are a considerable number of thermoelectric recorders; among the manufacturers of these instruments are: Siemens and Halske, Berlin; Hartmann and Braun, Frankfort a.M.; Pellin, Chauvin and Arnoux, Carpenter; and Richard, Paris; Queen, of Philadelphia; The Scientific Instrument Company, of Cambridge, England, and Rochester, New York; The Bristol Company, Waterbury, Conn.

¹³ *Zeitsch. f. Instrumentenk.*, 24, p. 350; 1904.

the record; thus in the Hartmann and Braun type, a silver stylus makes sulphide dots on a prepared paper; and in the Cambridge thread recorder, rectangular co-ordinates are obtained by having the galvanometer boom strike an inked thread which runs parallel to the drum.

As previously stated, these autographic instruments all give intermittent records and are limited to one or two speeds, and although they may be made very sensitive they are not adapted for the detection of transformations which take place very rapidly, since the recording interval cannot readily be shortened much below 10 seconds, and in most instruments this interval is greater than 15 seconds. In other words they can be used advantageously only for slow cooling.

II. θ vs t , θ' vs t (or θ vs θ').—In order to eliminate the effect of irregularity of outside conditions which influence the rate of cooling, a method commonly used when endeavoring to detect small transformations, consists in placing a second thermocouple in the furnace, but sufficiently removed from the substance studied to be uninfluenced by its behavior. Alternate

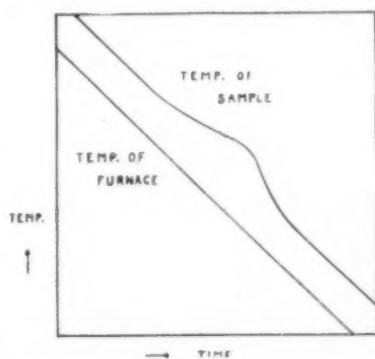


FIG. 4.—CURVE SHEET.

readings on the temperature of the test piece (θ) and of the furnace (θ') are then taken, preferably at definite time intervals. The data are most readily discussed by plotting the two temperature-time curves side by side, as shown in Fig. 4, or by plotting the difference in temperature $\theta - \theta'$ against the temperature θ of the test piece.

This method may be made recording, either by using two instruments or by modifying one of the above mentioned autographic recorders so as to trace the curves of two thermocouples on the same sheet.¹⁴ In practice, however, this method is usually resorted to only when great sensibility is desired, as in detecting minute internal energy changes, when the potentiometer combined with the deflection galvanometer is the most sensitive and quick-working arrangement for taking the measurements. It is convenient to use thermocouples of the same

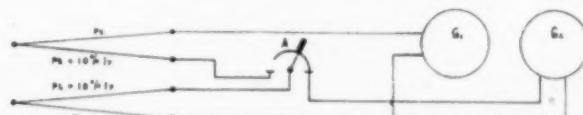


FIG. 5.—DIFFERENTIAL CURVE CONNECTIONS.

composition so as to have readings of both the temperature of the sample and of the furnace given by the same potentiometer setting, and so depend upon the galvanometer deflections for measuring the residual parts of θ and θ' .

Regarding the precision of this method, it is to be noted that the quantity it is really desired to measure is $\theta - \theta'$ in terms of θ , and this is accomplished by measuring θ and θ' , hence the sensibility of $\theta - \theta'$ is no greater than that of θ or θ' . In other words, the method requires the maximum refinement of meas-

¹⁴ The Siemens and Halske instrument has been so arranged. See *Zeitsch. f. Instrumentenk.*, 24, p. 350; 1904.

urement to obtain the quantity sought, as well as the maximum of computation or plotting to reduce the observations.

Differential Curves.

III. θ vs t , $\theta - \theta'$ vs t .—The preceding method II may readily be modified so as to give $\theta - \theta'$, the difference in temperature between the test piece and furnace, by direct measurement instead of by computation, with the added advantage that the precision of $\theta - \theta'$ may be made very great as compared with that of θ , the temperature of the sample. This may be accomplished, for example, by placing a commutator in the thermocouple circuit at A, Fig. 5, so that alternate measurements on θ and $\theta - \theta'$ may be taken in terms of the time. Evidently the connections may be so made that either the galvanometer G_2 of the same direct reading or potentiometer system that measures θ , or a separate instrument G' , as shown in the figure, may be used to measure $\theta - \theta'$.

Use of a Neutral Body.—Accidental variations in the indications of the auxiliary thermocouple giving θ' , the furnace temperature, may largely be eliminated by placing this couple within a blank or neutral substance. The material of the neutral body should be such that it undergoes no transformations involving an absorption or evolution of heat within the

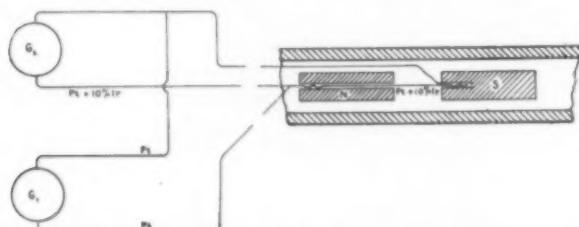


FIG. 6.—ROBERTS-AUSTEN DIFFERENTIAL METHOD.

temperature range studied, such as a piece of platinum, porcelain, or even in some cases nickel or nickel steel. It is also desirable that the sample and neutral have as near as may be the same heat capacities and emisivities. The sample to be studied and the neutral piece are placed near together and arranged symmetrically with respect to the temperature distribution within the furnace.

To Roberts-Austen¹⁵ again was due the credit of first devising a sensitive differential method using the neutral body. He also modified his photographic recorder (Fig. 1) so as to give, by means of a second galvanometer, the $\theta - \theta'$ vs t curve on the same plate with the θ vs t curve, from which a curve giving $\theta - \theta'$ in terms of θ could be constructed.

His arrangement of the direct reading and differential thermocouple and galvanometer circuits is shown in Fig. 6 in which S is the sample or test piece and N the neutral body possessing no transformations; the galvanometer G_2 measures the temperature θ of the sample, and G' measures the difference in tempera-

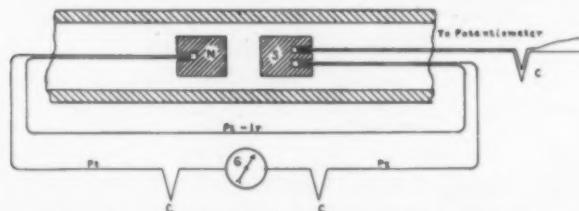


FIG. 7.—MODIFICATION OF DIFFERENTIAL METHOD.

ture $\theta - \theta'$ between the sample and the neutral. Curves for steels and alloys were usually taken with the samples in vacuo.

It is evident that Roberts-Austen's final photographic apparatus, although very sensitive, was also complicated and very delicate of adjustment, and in practice it took great skill in its

¹⁵ Fifth Report of the Alloys Research Committee, *Proc. Inst. Mech. Engrs.*, p. 35; 1899. *Metallographist*, 2, p. 186; 1899.

¹⁶ See for example: Carpenter and Keeling, *Collected Researches, Natl. Phys. Lab.*, 2, 1907.

use, requiring, for instance, some three or four successive exposures adjusted to the proper adjacent temperature ranges, to take the cooling curve of a steel from 1,100° to 200° C.

Most of the recent exact work¹⁶ employing the principle of this method has been done by taking the observations of θ directly on a potentiometer and $\theta - \theta'$ on the same or an auxiliary galvanometer. In this case of direct reading, the simple arrangement of thermocouples indicated in Fig. 5 may advantageously replace Roberts-Austen's (Fig. 6) or the modification shown in Fig. 7, such as used by Carpenter and others, thus dispensing with one thermocouple and the drilling of a second hole in the sample.

This method is evidently capable of attaining maximum sensitiveness, since the galvanometer connected to the differential thermocouple, giving $\theta - \theta'$ vs t , may be made as sensitive as desired independently of the θ vs t system. There is the further advantage that no limits are set to the range of temperatures over which a given precision in $\theta - \theta'$ may be had.

There is, however, a limitation on the certainty of interpretation of results by this method, especially when the rate of cooling is rapid, due to the fact that it is practically impossible to realize the ideal condition of having $\theta - \theta' =$ a constant, or keeping the cooling curves of the test piece and neutral parallel, for temperature intervals within which there are no transformations of the test piece.

The rate of cooling, and hence the value of $\theta - \theta'$, is influenced by several factors, among the most important of which are the mass of each substance—the unknown and the neutral—its specific heat, conductivity, and emissivity, as well as the relative heat capacities of the furnace and enclosed samples. The $\theta - \theta'$ vs t line is, however, always a smooth curve, except for the regions in which there are transformations in the substance under study.

The autographic system of recording may also be used and it is possible to construct an apparatus by means of which both the θ vs t and $\theta - \theta'$ vs t curves shall be recorded simultaneously on the same sheet by the same galvanometer boom. In order to accomplish this we have made use of a Siemens and Halske recording millivoltmeter having a total range of 1.5 millivolts and a resistance of 10.6 ohms.

The e.m.f. generated by the differential thermocouple, proportional to $\theta - \theta'$, is recorded directly by this instrument. 1° C. corresponds to from 16 to 19 microvolts between 300 and 1,100° C. for a platinum-iridium couple, or to about 1.8 mm on the record paper. In series with the Pt-Ir thermocouple giving temperatures is a suitable resistance, about 200 ohms in this case, so that the galvanometer boom may be kept within the limits of the paper when recording values of θ .

The circuit is made alternately through the direct and differential thermocouple circuits in series with the recorder by means of a polarized relay actuated by the same battery that depresses the galvanometer boom when the mark is made on the paper. The thermocouple circuits may be those of either Figs. 5, 6 or 7, but with the galvanometer G_2 indicating temperatures suppressed.

It is evident that by recording the two curves $\theta - \theta'$ vs t and θ vs t on the same sheet there is some sacrifice in the ability to detect small and rapid transformations, since the spacing is doubled. On the other hand, it is of great advantage to have the curves together and obtained independently of inequalities in clock-rates, which are a serious source of error in locating transformation points exactly when two separate instruments are used.

When it is desired merely to detect the existence of a transformation without measuring its temperature exactly, the sensitive form of recording millivoltmeter may be connected directly to the differential thermocouple without other accessories.¹⁷

IV. θ vs. $\theta - \theta'$.—It is sometimes of advantage to be able to record and discuss the data independently of the time, and so express $\theta - \theta'$, the difference in temperature between sample

¹⁷ Hoffman und Rothe, *Zs. Instrumentenk.*, 25, p. 273; 1905.

and neutral, directly in terms of θ , the temperature of the sample. This may evidently be accomplished by replotting the results obtained from the curves of the previous differential methods which involve the time. It was reserved, however, to Saladin, Engineer of the Creusot Works, to invent, in 1903, a method¹⁸ that would record photographically the θ vs $\theta - \theta'$

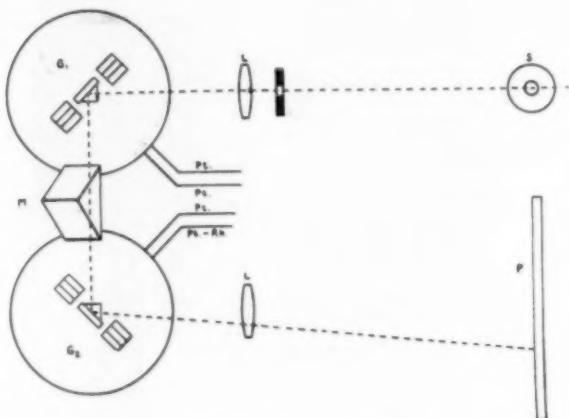


FIG. 8.—ARRANGEMENT OF TEST.

curve directly, thus obviating any replotting. His method possesses also the advantage of having the photographic plate fixed in place. The forms of curve obtained in this way are illustrated in Plate I, Fig. IV.

The arrangement of the apparatus in its simplest form, due to Le Chatelier,¹⁹ is shown in Fig. 8. Light from the source S strikes the mirror of the sensitive galvanometer G_1 , whose deflection measure the differences in temperature ($\theta - \theta'$) between the sample under study and the neutral body. The horizontal deflections of the beam of light are now turned into a vertical plane by passing through the totally reflecting prism M placed at an angle of 45° . A second galvanometer G_2 , whose deflections are a measure of the temperature of the sample and whose mirror in its zero position is at right angles to that of G_1 , reflects the beam horizontally upon the plate at P.

The spot of light has thus impressed upon it two motions at right angles to each other, giving, therefore, on the plate a curve whose abscissæ are approximately proportional to the temperature θ of the sample and whose ordinates are proportional to $\theta - \theta'$. The sensitiveness of the method depends upon that of the galvanometer G_1 , which may readily be made to give five or six millimeters for each degree centigrade.

The arrangement of the thermocouple circuits is the same as in Figs. 6 or 7. If so desired, the time may also be recorded by means of a toothed wheel driven by a clock and placed in the path of the beam of light. Compact forms of this apparatus, which are used considerably in metallurgical laboratories, are made by Pellin, Paris, and by Siemens & Halske, Berlin.

When steels and metallic alloys in the solid state are being investigated, advantage may be taken of the thermoelectric behavior of the sample itself to record the critical regions with Saladin's apparatus. Thus Boudouard²⁰ measures $\theta - \theta'$ by means of platinum wires set into crevices at each end of the sample, taking advantage of the fact that the transformation will usually be progressive along the sample.

This modification eliminates the neutral piece and one platinum or alloy wire, but, as Le Chatelier has shown,²¹ is less accurate than the usual form of Saladin's apparatus; and its indications may even be indeterminate or ambiguous, as the reaction may start midway between the embedded wires or at either end.

¹⁸ Saladin: New autographic Method to Ascertain the Critical Points of Steel and Steel Alloys, *Iron and Steel Metallurgy and Metallography*, 7, p. 237; 1904. First presented at Reunion des Membres Français et Belges de l'Association Internationale des Méthodes d'Essais 28 Fev., 1903.

¹⁹ H. Le Chatelier, *Rev. de Metallurgie*, 1, p. 134; 1904.

²⁰ Rev. de Metallurgie, 1, p. 134; 1904.

Saladin's method, it should be noted, is a perfectly general one for recording the relations between any two phenomena which may be measured in terms of e.m.f. or as the deflections of two galvanometers. This method cannot readily be made autographic, as this would require the simultaneous action of two galvanometer systems on a single pen. When used as a direct reading method it reduces to III.

IVa. θ vs $\theta - \theta' / \Delta\theta$.—For even moderately rapid cooling the differential method gives distorted curves which are often difficult of interpretation. This distortion is due largely to the different heat capacities and emissivities of the sample and neutral piece, thus causing differences in their rates of cooling in the furnace. Rosenhain has suggested (l. c.) that these irregularities may be eliminated by taking what he calls the "derived differential curve," or expressing the temperature θ of the sample in terms of the difference in temperature $\theta - \theta'$ between the sample and neutral for equal temperature decrements $\Delta\theta$ in the sample.

The experimental method is the same as in IV, but in addition it is necessary to replot the data obtained from the θ vs $\theta - \theta'$ measurements so as to give the value of $\theta - \theta'$ per degree change in temperature of the sample in terms of its temperature; but this appears to be worth while when the cooling curves of the sample and of the neutral differ considerably.

(To be concluded.)

Grinding.

By OSKAR NAGEL, PH.D.

The grinding of raw materials and finished products is of such industrial importance that the selection of the proper apparatus has to be made with the greatest care. The suitability of a mill depends upon the nature of the material to be handled, the capacity required and the fineness desired. The selection is greatly facilitated by the experimental laboratories which are maintained in the shops of many of the large manufacturers of mills and are at the disposal of prospective customers.

Generally speaking, grinding appliances can be divided into two types—machines for crushing and coarse grinding, and machines for the production of a fine powder.

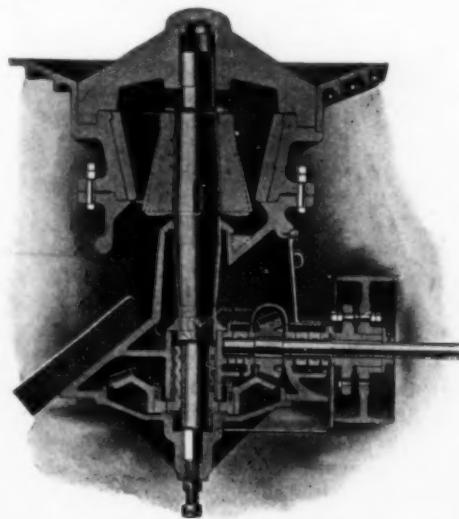


FIG. 1.—GYRATORY CRUSHER.

Gyratory Crushers—The gyratory type, shown in Fig. 1, which is used in almost all cement mills, as well as in other industries, has a vertical spindle on the upper end of which is mounted a chilled-iron crushing head, which moves inside a hopper-shaped top into which rock is fed. The bottom of the spindle passes loosely through an eccentric, driven from a horizontal shaft by bevel gears. The spindle, therefore, has a

²⁰ O. Boudouard, *Rev. de Metallurgie*, 1, p. 80; 1904.

gyratory motion, and may or may not rotate on its own axis. As the head, running eccentrically, approaches and recedes from the side of the hopper, the stone is gradually crushed and falls down between the crushing surfaces. The stone must be broken by hand to a convenient size to feed into the hopper. A crusher having a hopper about 40 inches in diameter and a crushing head about 20 inches will have a stroke of approximately $\frac{5}{8}$ inch.

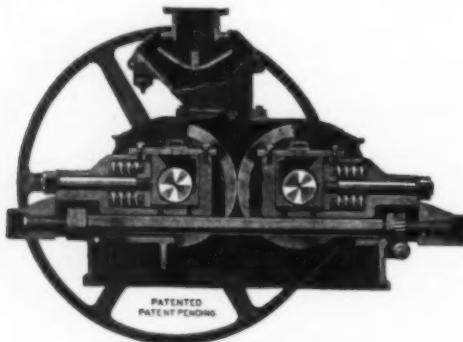


FIG. 2.—CRUSHING ROLL.

The horse-power necessary to drive averages 1 to 2 times the tons of rock crushed by hour, figuring on rock of moderate hardness. A crusher of this type is suitable for individual belt drive. Sometimes two or more crushers are belted to one motor, though this is not the best practice, as all crushers must be stopped when the motor is shut down. Gearing is not suitable for these machines, as the driving gear would be subject to severe strain should the crusher become clogged with rock.

Crushing Rolls.—These machines are built with plain or corrugated rolls. Their construction is easily understood from Fig. 2.

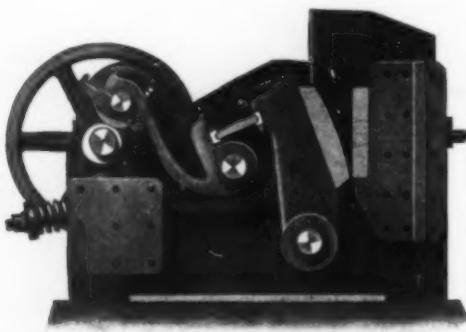


FIG. 3.—JAW CRUSHER.

Jaw Crushers.—In this type the pressing force of a moving jaw is utilized for crushing the material. This is a simple and effective crusher of moderate cost, capable of crushing the hardest material. It is illustrated in Fig. 3.

The Open-Door Rotary Fine Crusher, shown in Fig. 4, is built by the Sturtevant Mill Co., of Boston, Mass., in capacities from 1000 lbs. to 35 tons per hour. In this mill, which is widely used for soft and moderately hard materials, every part of the interior is easily accessible for replacement and inspection.

The Stamp Mill, shown in Fig. 5, is probably the oldest crushing machine and the most convenient for certain materials, as it does not get out of order and requires very little attendance.

Ball Mills.—In cement works these mills take the output of the crushers and reduce it to a coarse grit. A drum, having a diameter of about double its length, is filled with steel balls and revolves around a horizontal axis at a speed of from 21 to 27 revolutions per minute. The lining of the drum is made up of overlapping steel plates which form steps. As the drum revolves, the balls drop over the steps, pounding the material to pieces.

The tube mill consists of a wrought iron tube mounted on a shaft by the attachment of heads so formed as to make trunnions, which rest in bearings at both ends or supported by tires securely attached to the shell. A large gear attached to the tube and a pinion attached to the pulley shaft make the actuating device. The tube is lined with silex stone, and is about one-half filled with flint pebbles. The large grinding surface thus provided permits of a very slow rotation, 22 to 27 revolutions per minute, according to the size of the machines. The trunnion at the feed end is hollow, and a screw conveyor carries in the material. By simply regulating the feed, any degree of

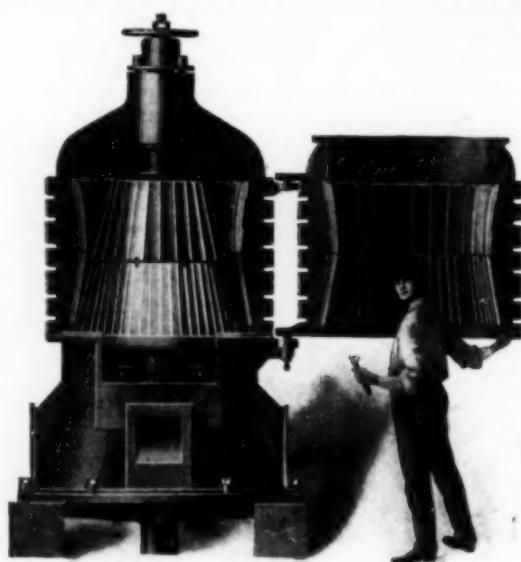


FIG. 4.—OPEN-DOOR ROTARY.

fineness, even to impalpable powder, may be obtained. Fig. 6 shows the tube mill built by F. L. Smith & Company, New York. Fig. 7 shows the spiral feed and discharge which are the characteristic features of the tube mill of the Abbe Engineering Co. A detailed description of the popular tube mill of this company will be found in Vol. III, p. 6, of this journal.

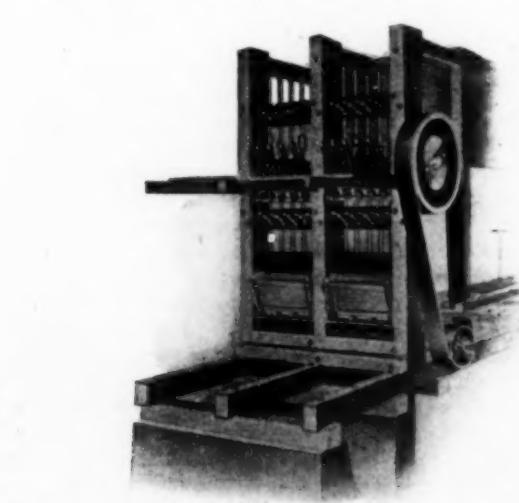


FIG. 5.—STAMP MILL.

Kominuters.—The kominuter is one of the latest developments on the line of low speed coarse grinders. It combines to some extent the best features of the ball mill and the tube mill, resulting in increased capacity per horse-power, and a decreased cost of repairs over ball mills; compared to a ball

mill having the same volume of grinding room, and requiring approximately the same horse-power, the kominuter can carry more balls than the ball mill; it has also more screen surface and has a higher efficiency per square foot than the ball mill, the wire cloth being the same in both cases. The kominuter gives a higher output per horse-power than the ball mill, is

tained; the roll revolves against the die in the direction of the pulley, and this contact causes the roll and shaft to revolve around their own axes in opposite directions. These mills are best adapted to belt-drive, and may be driven by a vertical motor, or a horizontal motor with a quarter-turn belt. The Griffin mill is manufactured in two sizes—30 inch and 36 inch—

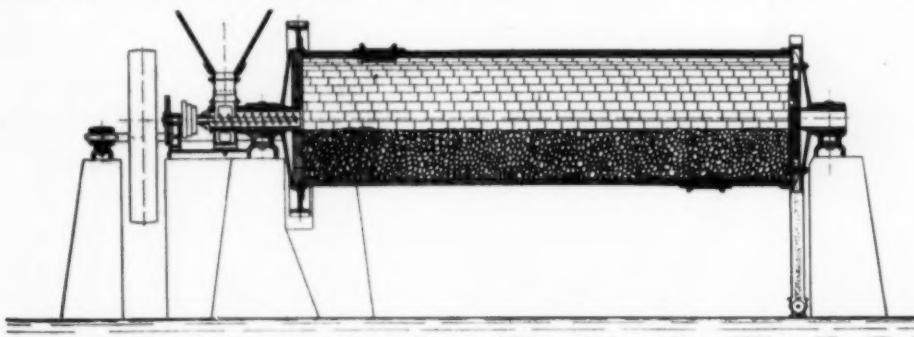


FIG. 6.—TUBE MILL.

self-contained, is provided with automatic feed, and automatically returns to the mill the tailings from the screens. Fig. 8 shows a kominuter built by F. L. Smith & Co., New York.

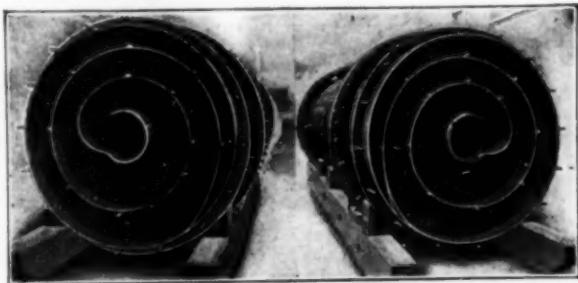


FIG. 7.—SPIRAL FEED AND DISCHARGE.

Griffin Mills.—These mills are used for the fine grinding of cement and other materials. The mill shown in Fig. 9 is driven from a pulley at the top, revolving on a vertical axis. The power is transmitted to a vertical shaft, which is hung from a universal joint inside the pulley and is free to move in any

designated according to the diameter of the ring against which the crushing roll revolves.

A new mill has been brought out by the manufacturers of the Griffin mill (The Bradley Pulverizer Co.) called a Three Roll Griffin Mill. This is similar in its action to the standard mill, but, as the name implies, has three crushing rolls instead of one.

Fuller Lehigh Mills.—These are called Fuller mills. They are used on the same material as the Griffin mill described above, and the grinding is done by four chilled-iron balls about 9 inches in diameter that are propelled by four equidistant horizontal arms or pushers radiating from a vertical central shaft. The orbit is a circular die against which the balls exert great pressure, since they weigh about 112 pounds each and revolve at about 210 revolutions per minute. The main shaft is driven from a pulley mounted at the bottom below the grinding level. This mill, which is shown in Fig. 10, is built by the Lehigh Car Wheel & Axle Works, Catasauqua, Pa.

The Kent Pulverizer, which is also widely used for coarse and fine grinding, is illustrated in Fig. 11 in a sectional view. The ring revolves and the three rolls press against its inner face. These are the only four wearing parts. The rolls are convex and are provided with guides, while the ring is concave.

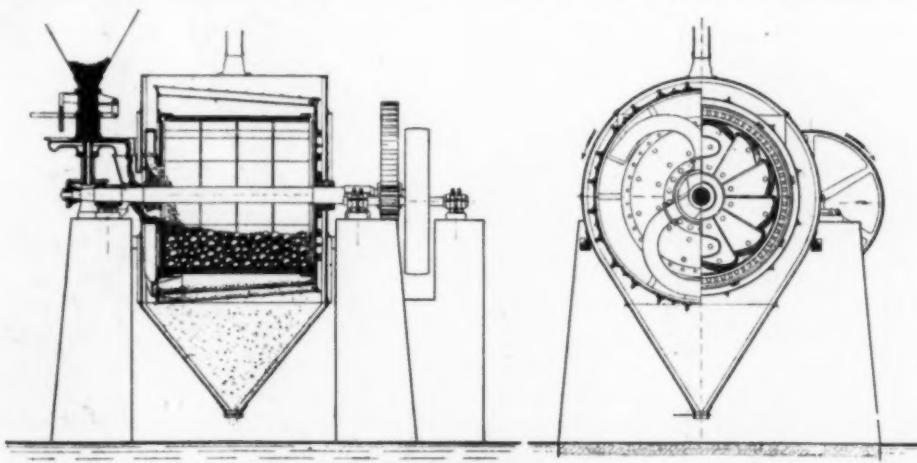


FIG. 8.—KOMINUTER.

direction at the bottom. A crushing roll is rigidly connected to the bottom of the shaft. When the pulley revolves the crushing roll is thrown off center and revolves against a fixed ring or die with a centrifugal force of about six thousand pounds pressure. The grinding is done between these two surfaces.

Two distinct actions on the material to be ground are ob-

tailed; the roll revolves against the die in the direction of the pulley, and this contact causes the roll and shaft to revolve around their own axes in opposite directions. These mills are best adapted to belt-drive, and may be driven by a vertical motor, or a horizontal motor with a quarter-turn belt. The Griffin mill is manufactured in two sizes—30 inch and 36 inch—

The rock falls from the inlet to the inner face of the ring. Centrifugal force holds it there in a layer an inch deep. It

revolves with the ring, and passes under the rolls. The rolls are pressed by the springs outwardly against the rock on the ring with a pressure adjustable to 20,000 lbs. by the screws against the springs. The rolls pass over the rock, crushing it against the ring. The crushed rock falls off each side of the

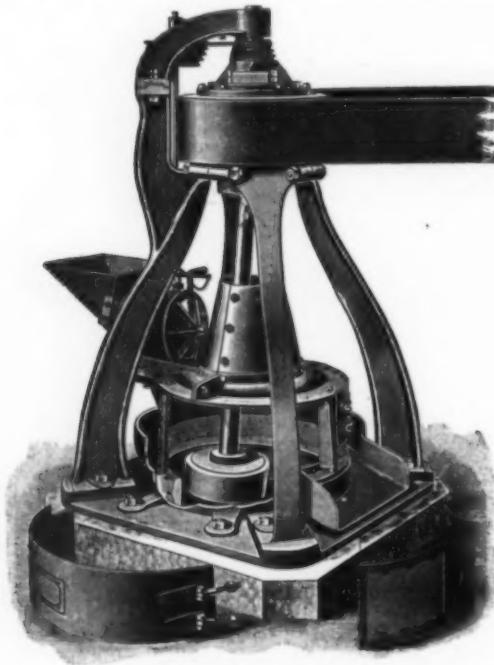


FIG. 9.—GRIFFIN MILL.

ring into the casing and thence to the discharge. The body of the rock between the rolls and the ring make 90 per cent of the rock abrade on itself in crushing, thus reducing the wear on the moving parts. This mill is built by the Kent Mill Co., New York.

Impact Pulverizer.—A mill which is widely used on account of its convenient accessibility to its inner parts is built by the

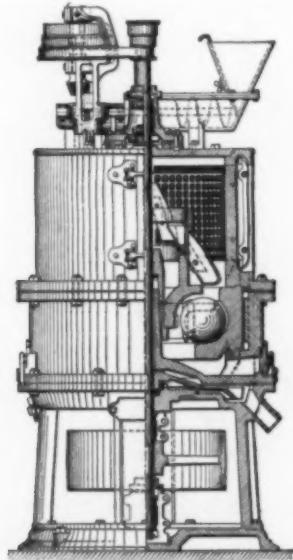


FIG. 10.—FULLER MILL.

Raymond Brothers Impact Pulverizer Company, of Chicago. For grinding finer than to 100 mesh, air separators are attached to this mill, as illustrated in Fig. 12.

For pulverizing coal and for transporting the coal dust mixed with the amount of air necessary for combustion to a kiln or

furnace the so-called **Aero Pulverizer**, shown in Fig. 13, is successfully used. This machine consists of several chambers of successively increasing diameter with interior communication in which revolve paddles on arms with correspondingly increased radii. Three of these chambers are in fact separate pulverizers on a single axis, each succeeding pulverizer having longer arms and therefore greater speed at the periphery, and greater power for fine pulverization. The fourth chamber con-

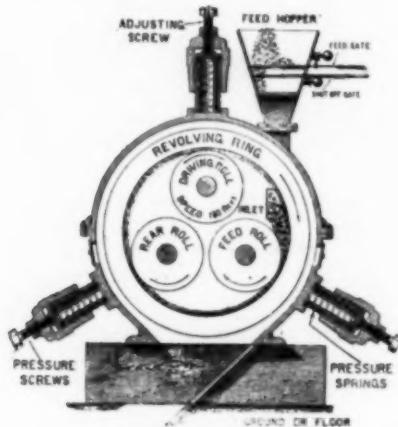


FIG. 11.—KENT MILL.

tains a fan whose function it is to draw the more finely pulverized material successively from one chamber to the other and finally to deliver it through a pipe connection to the furnace with the impetus of a forced draft. The three pulverizers and fan are enclosed in one steel cylinder.

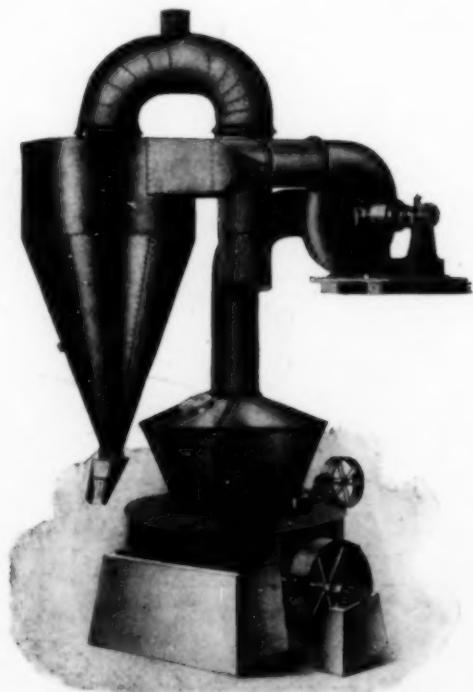


FIG. 12.—IMPACT PULVERIZER.

A regulating feed device accurately controls, and by moving a lever, varies the quantity of coal admitted to and delivered by the machine. The inlets in the feed device admit the air required for pulverizing purposes. An auxiliary inlet between the third work chamber and the fan is controlled by a damper and admits such additional air as is required to bring the total

air supply up to the theoretical requirement. The auxiliary air is intimately mixed with the pulverized coal in the fan



FIG. 13.—AERO PULVERIZER.

chamber. These machines are built by the Aero Pulverizer Co., of New York.

Notes on Electrochemistry and Metallurgy in Great Britain.

(From Our London Correspondent.)

The Institution of Mining and Metallurgy.

Accumulation and Absorption of Gold Amalgam by Copper Plate.

Owing to pressure of other matter notice of two papers on this subject discussed at the meeting on May 21 has been held over. The first of these, by EDWARD HALSE, gives detailed particulars of the gold retained by three sets of silvered plates (apron) in a mill at Sucre, Colombia, which had accumulated during a period of rather more than six years. The one milled was pyritic and consisted mainly of quartz with some (rarely visible) free gold.

The four plates of the first set were taken up at the end of 26 months and "burnt." During that period 4462 tons of high-grade ore passed over them, with an average yield of 19.62 dwt. of fine gold, followed by 3453½ tons of tailings, with an average yield of 2.58 dwt. of fine gold per ton (2000 lb.).

The gold scale from the four plates weighed 937 oz., and the average rate of accumulation was 1.269 dwt. of fine gold per ton milled.

The four plates of the second set were taken up at the end of a similar period, during which 1172 tons of tailings, with an average yield of 1.95 dwt. of fine gold, followed by 2175 tons of low-grade ore, with an average yield of 6.80 dwt. of fine gold per ton passed over them.

The gold scale amounted to 568 oz., which gives an average rate of accumulation of 1.823 dwt. of fine gold per ton milled.

The four plates of the third set were allowed to run for 24 months only. The ore crushed during that period amounted to 2869 tons of medium grade, yielding 11.13 dwt. of fine gold per ton.

The gold scale from these plates weighed 553.68 oz., giving an average rate of accumulation of 2.071 dwt. of fine gold per ton.

The average accumulation of hard amalgam per ton works out at 1.721 dwt. of fine gold. At the Drum Lummon mine, about 12 years ago, Mr. R. T. Bayliss obtained an average of 0.499 dwt. fine gold per ton milled. The grade of ore at Sucre was about double that at Drum Lummon; and, no doubt, other things being equal, the richer the ore the greater the accumulation. From the results at Sucre it would appear that the richest

ore gave the lowest rate of accumulation, but this is accounted for by abnormal conditions, interruption and milling of tailings. The author states that it is well known that very low grade ore will gradually remove hard amalgam that has accumulated on plates from rich ores which has previously passed over them, and considers the low rate of accumulation with the first set is thus explained. In the case of the second set of plates there was practically no "scouring" for the milling of the low-grade tailings was followed and not preceded by the milling of ore (low grade). During the third period the conditions were quite normal. Medium-grade ore had by that time become available, and no tailings were passed through the mill. So that, at Sucre, working under normal conditions, the average rate of accumulation of hard amalgam was as much as 2 dwt. of fine gold per ton, or four times higher than was the case at Drum Lummon. The gold actually *absorbed* by the plates, and only recoverable by melting them down, was 0.288 grain per ton milled at Drum Lummon, and certainly less than 1 grain per ton at Sucre. The average rate probably does not exceed a fraction of a grain per ton.

The other paper was by W. E. THOMAE, who quoted the statement made to him by the manager of a large gold mine on the Rand that "every new plate in a gold mill will absorb and lock up about 70 oz. of gold;" and remarked that one frequently hears the statement, when a new mill has started with a disappointing return, that it was due to the absorption of gold by the new plates. To what extent is this justified? If the two statements were combined one might jump to the conclusion that the first crushing return of a new mill is reduced by about 70 oz. for each copper plate it contains. Such a conclusion, however, would require very considerable modification.

Consideration of results obtained at the Drum Lummon and Hidden Treasure mines by R. T. Bayliss and A. L. Collins, respectively, appear to justify the following general conclusions:

1. The amount of gold actually absorbed by a copper plate, 4 ft. 6 in. x 8 ft. to 12 ft., is not likely in the long run to amount to more than 8 to 10 oz., and generally not more than half of this, if as much, will affect the first month's crushing returns.

2. The amount of gold retained on a plate in the form of amalgam scale is a variable factor, depending largely on the capacity of the millman and the discretion of the manager.

Though apparently there are cases where the amalgam scale is allowed to accumulate to a large extent, that is not the general practice, and in any case the accumulation during the first month, when the plates are new, will represent only a proportion of the final accumulation.

Thus it would appear that generally the first month's run of a gold mill with new plates is not affected by such a serious loss in locked-up gold as is sometimes attributed to it, or inferred.

Finally, in connection with this subject, the author enquired why Muntz metal plates are not more generally used. They should be cheaper than copper plates, they absorb practically no gold, the amalgam scale does not adhere to them so obstinately and they are hence more easily cleaned up.

The Mining Exhibition.

As is natural in a country whose chief mineral wealth is carboniferous, the chief features of the Mining Exhibition held in London this month have had relation to the use of electricity in coal mines. Haulage gear, conveyors and coal cutters, electrical safety lamps, motor-driven centrifugal pumps, were exhibited in both old and new patterns. An Ingersoll Rand electric air drill calls for mention as new to British practice. This apparatus consists practically of an ordinary compressed air percussion drill actuated by a small electrically-driven compressor on a truck. The main advantage claimed for this system of drilling is that it combines the economy of electrical as against pneumatic transmission, with the simplicity and cushioned blow of the air drill, and only requires about one-fifth of the power of the latter. The cylinder is divided into two parts, each with its own piston. Each piston is driven by the air from

one air cylinder of a small electrically-driven air pump without valves by means of a separate tube. The two drill pistons run synchronously with the air-pump pistons, and the quantities of air in each half of the drill cylinder act as air cushions at the same time. The air is always the same, and is saturated with oil so as to act as a lubricant. This drill is exceedingly simple and requires very little repairing. The output or speed of the strokes can easily be varied by means of the motor driving the air pump. It requires, of course, more room than the purely electric drills on account of the air pump, although this is very compactly arranged, but is quite suitable for large stoves and easy tunneling work. The outfit shown is driven by a 2-hp, three-phase motor, and is intended for holes 6 to 8 ft. deep.

The Grondal Kjellin Company, Limited, exhibited a model of a Kjellin induction steel furnace. The model exhibited, however, has not the renewable hearth with which the latest types are fitted. Samples of steel produced in the Kjellin and Rochling-Rodenhauser electric induction furnaces are also exhibited. Samples of electrically-melted steels, including diamond-tungsten and chrome steels are shown by Messrs. Sybry, Searls & Company, Limited, of Cannon Steel Works, Sheffield, who produce all these classes of steel from the raw Swedish iron by means of the Kjellin furnace.

Scientific and Technical Symbols.

A subcommittee of the International Electrical Commission has recently been advocating an attempt to establish a system of scientific symbols which shall be the same for all languages. While chemistry has the great advantage of being equally comprehensible throughout the learned world, electricity requires of the student further education if he is to understand the many valuable contributions to knowledge on the subject continuously emanating from, for example, France and Germany. The simplification of international patent specification would also be invaluable, as, at the present time, it requires not only an acquaintance with the colloquial portions of a foreign language, but also an intimate experience of the technical equivalents to check the foreign version of a patent. In an article written at the request of the subcommittee above mentioned, Mr. Miles Walker, while recognizing the desirability of a recognized code of symbols, admits at once the two leading difficulties in the way of establishing it. In the first place there is the difficulty of training the mind in the case of persons thoroughly and daily accustomed to recognize a certain symbol as having a certain meaning to ascribe to it a quite different meaning; and, in the second, the fact that there are not enough letters in the two or three alphabets in common use to give a distinct symbol to each quantity. The use of combinations the writer very reasonably objects to as hindering the classification of the quantities of the same kind by the simple addition of subsidiary figures or lettering now in common use. He suggests the creation of new symbols to meet the latter difficulty. As this has already been done, for a somewhat similar purpose, in the various systems of shorthand with entirely satisfactory results, this expedient seems quite feasible. The publication and deposit at some suitable establishment (such as the library of one of the scientific institutions) of a code of symbols would ensure their permanency of signification in case of legal or other dispute as to their meaning. The spread of typewriting may be taken as either for or against this proposal. On the one hand, the elimination of difficulties caused by illegible writing is secured, while, on the other, the size of the machine must be much increased to comprehend all the symbols likely to be in use.

Reinforced Concrete.

The question of the durability of the steel structure in concrete has often been raised without very much practical data as a result. At the National Physical Laboratory (London) some tests were recently carried out at the request of Sir John Brunner to determine the effect produced on mild steel by being embedded in concrete. The official report is as follows:

"A strong wooden box was made and divided into five partitions, each partition being 12 in. long, 7½ in. wide and 7½ in. deep. Specimens of mild steel of the following dimensions were prepared: (1) 1 in. in diameter, 8 in. long, turned all over; (2) 8 in. lengths cut from a 1½ in. by 1½ in. bar with the scale left on. The partitions were half filled with good Portland cement concrete, and a specimen of each kind laid on the top, and the partitions were then filled up. This was done on December 21, 1906. The blocks were covered with water several times a week for a year, and for three months afterwards were left in the open subject to the weather. On April 20th one of the blocks was removed from the box and broken up, and the specimens removed. On examining the specimens carefully no trace of any action by the cement could be detected. The turned specimen was practically as bright as when it was put in, and the scale on the rough specimen was undisturbed. To test the possibility of any slight action the surface of the turned specimen was polished and etched and examined under the microscope side by side with a specimen of the same material cut from the center of the bar. No difference in the micro-structure of the two specimens could be detected, and the conclusion is that in sixteen months no action has taken place between the metal and the concrete. It is proposed to immerse one of the remaining blocks in the comparatively warm water of the cooling pond for six months, and then to examine the specimens."

While these experiments are of the highest value, it will be of still greater interest if it can be ascertained what effect samples of concrete taken from actual working mixtures in use in various cities would have under similar circumstances.

Market Report for July.

Tin has fluctuated considerably during the last month. Starting on the 1st at £124 per ton, unusually low, it commenced to rise gradually, and afterwards sharply, till by the 9th it had reached £132. It then fell to £130, rising, however, by the 17th to £135. Another drop followed, after which the price rose to £138 on the 30th.

Copper has been fairly steady throughout the month at or about £58, rising during the last week to £60. Prices on the 30th, £59.50.

Eng. Lead has been firm at about £13.50 during the month. *Hematite*: Steady throughout the month at 58/-.

Cleveland Warrants: Tendency lower. 51/- up to the 18th, then falling gradually to 50/-. Price on the 30th £29.10½.

Scotch Pig: Steady in the neighborhood of 56/-, with inclination to lower after the 15th.

Chemicals:

Ammonia Sulphate F.O.B. Liverpool, per ton.....	£11. 17. 6
Copper Sulphate, per ton.....	20. 6. 0
Caustic Soda, 77 per cent, white, per ton.....	11. 2. 6
Bleaching Powder, 35%, per ton.....	4. 5. 0
Antimony, Regulus, per ton.....	£33 to 34. 0. 0
Shellac, Standard T. W. Orange spots, per cwt.....	6. 10. 0
Carbolic Acid, liquid 97 to 99%, per gal.....	11
Creosote, good ordinary liquid, per gal.....	2 1/16
Naphtha Solvent, 90% at 160° C., f. o. b., gal.....	10
Rubber, Para fine, per lb.....	3. 8 1/4

American Electrochemical Society. At the last meetings of the board of directors the following gentlemen were elected members of the society: E. G. Acheson, Jr., Niagara Falls, N. Y.; William H. Arison, Niagara Falls, N. Y.; William C. Bray, Boston, Mass.; W. R. Clymer, Cleveland, Ohio; Orin E. Dunlap, Niagara Falls, N. Y.; C. M. FitzGerald, New York City; Charles E. Foster, Rochester, N. Y.; A. J. Guerber, Allentown, Pa.; Henry D. Hibbard, Plainfield, N. J.; George M. Kebbe, Brooklyn, N. Y.; C. Le Boutillier, High Bridge, N. J.; A. S. McAllister, New York City; E. C. Sprague, Niagara Falls, N. Y.; John H. Thickens, Appleton, Wis.; George N. Tidd, Scranton, Pa.; Edmond A. White, Port Kemble, New South Wales, Australia. The fall meeting will be held on Oct. 29, 30 and 31 in New York City. The spring meeting, next year, will be held in Niagara Falls. The thirteenth volume of the *Transactions* has just been issued. It is a fine volume of 48 pages and contains the complete record of the last meeting held in Albany.

SYNOPSIS OF PERIODICAL LITERATURE.

Theoretical and Experimental.

Formation of Metallic Dust from Cathodes in Dilute Gases.—F. Kohlschütter and Th. Goldschmidt have studied experimentally the formation of metallic dust from cathodes in glow discharges and give an account of their research in *Zeit. f. Elektrochemie*, April 24. It has already been found before that the quantity of dust produced depends not only on the nature of the metal, but also on that of the gas in the discharge tube. This has led to a chemical theory of the phenomenon, according to which the cathodes are attacked in dilute gases, whereby endothermic compounds of gas and metal are formed, which then decompose again, giving off metallic dust. In the present investigation the phenomenon was studied quantitatively, with special reference to the above theory. Cathodes of Al, Fe, Cu, Ag, Pt and Au were used in H₂, He, N₂ and Ar. While the cathodic formation of dust has some similarities with the dust formation from electrically heated incandescent wires, yet it is not certain that both phenomena do belong together. At higher pressures (1 mm) the dust formation is not caused by the escape of occluded gas from the cathodes. Small quantities of oxygen in another gas do not increase the cathodic dust formation in such an abnormal way as is the case with an incandescent wire. The metals can be arranged in a series according to their liability of dust formation and their order in this series is the same in all gases. The loss of weight of the cathodes is proportional to the equivalent weight of the metal, other things being equal. The gases may also be arranged in a series according to their ability of attacking the cathodes, and their order in this series is the same for all metals. It is the same order as that of the atomic weights. *Zeit. f. Elektrochemie*, July 3, contains a preliminary account of an investigation of the same phenomenon by F. Fischer and O. Haehnel, who always used two discharge tubes in series. If the pressure of the gas is the same and the same cathodes are used in both tubes, the same quantity of dust is formed in both. If the gas pressure is not the same, the formation of dust is approximately inversely proportional to the gas pressure. The result of Kohlschütter and Goldschmidt that the order of the gases is the same as that of the atomic weights is contradicted. V. Kohlschütter replies to these criticisms in *Zeit. f. Elektrochemie*, July 31, explaining the scope of his extended investigations on this subject.

Electroanalysis.—The polemics between F. Foerster and A. Classen concerning high-speed methods in electroanalysis is continued in *Zeit. f. Elektrochemie*, April 17 and 24. In the same journal, May 8, O. Scheen discusses the electroanalytic determination of antimony, while in the issue of May 29, E. Cohen criticizes some points in this paper. The electrolytic determination of nickel in nitrate solution and its separation from copper is discussed by A. Thiel in *Zeit. f. Elektrochemie*, April 17. He finds that the electroanalysis of nickel in nitrate solutions is always successful, if proper precautions are taken (for instance, use of straight passive iron wires as anodes).

Silver Peroxide.—From experiments with a diaphragm cell, containing silver nitrate in both compartments and having an anode and a cathode of platinum, with an anodic current density of 0.07 ampere per square centimeter, G. Baborovsky and B. Kuzma (*Zeit. f. Elektrochemie*, April 10) conclude that the primary formation of silver pernitrate, Ag NO₄, at the anode, is very probable.

Electrolysis of Fused Calcium Chloride.—According to K. Arndt and K. Willner (*Zeit. f. Elektrochemie*, April 17) the decomposition voltage of fused calcium chloride at 800° C. is about 3.24 volts.

Chemical Thermodynamics.

Nernst's Theorem.—In recent years W. Nernst, with many of his students, has paid special attention to a new theorem of

thermodynamics. The well-known Gibbs-Helmholtz equation states that $A - Q = T \frac{dA}{dT}$, where A the change in free energy (the maximum amount of work obtainable from the reaction at the constant temperature T, if carried out in a reversible way), Q the "latent heat of the reaction" (the change in total energy, if the volume remains constant), and T the absolute temperature. At the absolute zero point of temperature A evidently equals Q. Nernst's new theorem makes the further assumption that $\lim \frac{dA}{dT} = \lim \frac{dQ}{dT} = 0$ for T = 0. This hypothesis leads to very interesting consequences. (The best summary of the whole theorem, now available to American readers, is continued in Nernst's lectures, held at Yale in 1906, on Experimental and Theoretical Applications of Thermodynamics to Chemistry, recently published in book form by C. Scribner's Sons.) Two recent investigations refer to this theorem. The equilibrium $\text{SO}_2 + \text{Cl}_2 \rightleftharpoons \text{SO}_2\text{Cl}_2$ is studied by M. Trautz, E. Baisch and A. von Dechend in *Zeit. f. Elektrochemie*, May 15. The application of Nernst's theorem to the thermodynamical calculation of electromotive forces is discussed by F. Halla in *Zeit. f. Elektrochemie*, July 24. The experimental results obtained with the two cells Ag, Ag Cl Pb Cl₂ (saturated), Pb and Ag, Ag Cl Hg₂ Cl₂ (saturated), Hg are found to be in good agreement with Nernst's theory.

Ammonia Equilibrium.—The old controversy between W. Nernst and F. Jost on one side and F. Haber on the other side concerning the exact figures for the equilibrium of the reaction $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$ is reopened by F. Haber and R. LeRossignol in *Zeit. f. Elektrochemie*, April 10, where they give an account of determinations of the equilibrium at various temperatures up to 1,000° C. and at a pressure of 30 atmospheres. The results confirm former results of Haber and Van Oordt for atmospheric pressure and their figures disagree at higher temperature to some extent from the experimental results of F. Jost. The latter, in his reply in *Zeit. f. Elektrochemie*, July 10, thinks, however, that the disagreement is not so very bad.

Industrial Electrochemistry.

Silicon as Reducing Agent.—B. Neumann discusses again (*Zeit. f. Elektrochemie*, April 3) the use of silicon as reducing agent for refractory oxides. In an electric furnace with two vertical electrodes (Heroult type) he melts lime or alumina or a mixture of both, and to this highly heated bath (melting point 1,400° to 1,450° C.) he adds a mixture of the refractory oxide to be reduced (for instance, of chromium) and an equivalent amount of silicon or ferrosilicon. The reaction then starts at once, the silica which is formed is absorbed by the lime-alumina mixture, while the reduced metallic particles (of chromium, etc.) sink to the bottom and form a regulus. The author made experiments on the production of ferrochrome, ferrotungsten, titanium and molybdenum. It is possible to produce in this way low-carbon metals or alloys, but they always contain some silicon (some 2 per cent), but this the author considers to be no disadvantage for the steel industry.

Discharges Through Gases.

Fixation of Atmospheric Nitrogen.—The question whether the combination of nitrogen and oxygen as a result of an arc discharge through air is purely a thermal effect (so that the electric discharge simply serves for heating the air) or whether there is a specific electric effect involved, is discussed by G. Brion in *Zeit. f. Elektrochemie*, May 1. Simple heating of air causes, of course, combination of oxygen and nitrogen, but the question is whether in an electric discharge there is not an additional specific electric effect. If the ionic theory is applied to gases heated by electric discharges we have energy centers of maximum kinetic energy, surrounded by zones of gradually diminishing energy. It is difficult to apply the conception of purely thermic formation of NO from N and O to such conditions of the electric discharge. In the first place, if we take the resulting total heating of the gas mass as the basis of the thermodynamical calculation of the NO formation, we

get much smaller values than are found in practice. On the other hand, all thermic theories are based on the applicability of the law of mass action, and this is hardly applicable for electric discharges, especially at low current densities. For this reason the thermal theory leads to wrong conclusions for glow discharges, while the conclusions are in better agreement with the results obtained at high temperatures (4,000° C.) with large quantities of energy.

Ammonia Formation.—Similar problems are discussed by M. LeBlanc and J. H. Davies in *Zeit. f. Elektrochemie*, July 3, with special reference to the equilibrium $3\text{H}_2 + \text{N}_2 = 2\text{NH}_3$. The formation of ammonia under the influence of the silent discharge was studied and it is found that the law of mass action no longer holds good. In the first moments of the electric operation the output of ammonia is a maximum, but is not high enough to render commercial application of the process promising. "If in an electric field (zone of electric action) the law of mass action is found to hold good, we can conclude that the equilibrium corresponds to the thermodynamical principles. If not, we can assume that we have to do with a more or less specific electric effect."

Batteries.

Edison Accumulator.—In *Zeit. f. Elektrochemie*, May 22, F. Foerster gives a further account of his very extended researches on the Edison iron-nickel cell. In the present paper he deals especially with the behavior of the electrolyte during charge and discharge and shows that it does not remain unchanged, as was originally supposed. The reaction at the nickel electrode appears to be $\text{Ni}_2\text{O}_3 \cdot 1.2\text{H}_2\text{O} + 1.8\text{H}_2\text{O} = 2\text{Ni}(\text{OH})_2 + 2\text{OH}^- + 2\text{F}$, where F is a positive charge of 96,540 contents. (A somewhat different reaction is assumed by Zedner, who writes $4\text{H}_2\text{O}$ instead of $1.8\text{H}_2\text{O}$.) The reaction at the iron electrode appears to be $\text{Fe} + 2\text{OH}^- = \text{Fe}(\text{OH})_2 - 2\text{F}$. Hence the total reaction of charge and discharge of the Edison cell is $\text{Fe} + \text{Ni}_2\text{O}_3 \cdot 1.2\text{H}_2\text{O} + 1.8\text{H}_2\text{O} = \text{Fe}(\text{OH})_2 + 2\text{Ni}(\text{OH})_2$. During discharge the electrolyte becomes more concentrated, during charge it becomes more dilute. Foerster discusses in detail the changes of specific gravity of the electrolyte during charge and discharge, and the influence of the concentration of the electrolyte on the e.m.f. In agreement with the theory, the e.m.f. decreases with increasing concentration.

Gold.

The Use of Borax in Assaying Gold Ores.—The results of some experiments carried out by Mr. J. E. Clennell on an ore similar in general character and appearance to Rand blanket ore, but practically free from pyrites, though carrying considerable quantities of iron in the form of black oxide, perhaps titaniferous, lead him to the following conclusions: 1. A large excess of borax gives a hard, stony slag, very difficult to separate clean from the lead button. In hammering out, the slag flies to pieces violently carrying with it a portion of the lead. Some part of the latter is sure to be lost unless extreme care be taken in collecting all the fragments. This, in the author's opinion, may explain some of the observed losses in the use of borax. 2. When no borax at all was used, the button usually separated quite clean from the slag. The latter was amber-colored and, while cooling, a scum of straw-colored crystals collected on the surface. The addition of borax rendered the slag distinctly more fusible. 3. The non-borax flux was considerably more deliquescent than the ordinary borax flux; it, however, caused no inconvenience, unless the fusions happened to be left in the molds for some hours after pouring. 4. By using a small quantity of borax in the charge, not exceeding 5 to 10 grams per assay ton of ore, it was found that a uniform fusible slag was produced without any noticeable amount of the above-mentioned scum. The buttons could be detached from the slag by a slight blow and none of the lead adhered to the slag. An average of 297 assays made without borax gave 18,169 dwt, while an average of 297 assays made on the same samples, with similar fluxes, but containing borax, gave 18,185

dwt, thus showing a slight advantage for the borax flux. The fluxes finally adopted were as follows:

Mine and mill	Cyanide and	Cyanide	
Flux, parts by weight:	samples.	slimes.	residues.
Bicarbonate of soda.....	2500	2400	3600
Fused borax glass.....	200	200	400
Litharge	2500	2400	3600
Charcoal	60	50	60
Weight of charge:			
Ore for assay.....	1 A. T.	2 A. T.	2 A. T.
Flux (grams)	120	200	300
Cover of soda (grams).....	10	15	20

—*Jour. of Chem., Met. & Mining Society of South Africa*, April, 1908.

Iron and Steel.

In the following notes we give brief abstracts of Iron and Steel Institute reports on research work carried out during 1907-08 by holders of Carnegie research scholarships.

Rusting of Iron.—Mr. J. Newton Friend reports on some experiments from which he concludes that the rusting of iron is primarily the result of acid attack. He found that steel and the purer forms of iron can be kept for an indefinite time in the presence of pure water and air without undergoing the slightest change. The introduction of the merest trace of acid, however, causes immediate corrosion. Cast iron, on the other hand, rapidly rusts in the presence of pure water and air "owing to the catalytic or electrolytic action of its numerous impurities." Neither water and air nor steam and air, at 100° C., exert any action on the purer forms of iron, though a layer of oxide is immediately formed on introducing a trace of carbon dioxide. When iron has once begun to rust, further corrosion proceeds rapidly. This is due to the hygroscopic nature of rust, whereby its pores become saturated with moisture charged with carbonic acid. Hence, iron which has once begun to rust continues to do so in a moist atmosphere where rust-free iron would not be affected. The present author has succeeded in preserving a piece of partially rusted iron in contact with pure air and water without the slightest increase in the rusted area being apparent.

Sodium for Steel Refining.—Mr. A. Hiorth's report contains an incidental remark which will be interesting to electro-metallurgists. It appears that Mr. Ashcroft's electrolytic sodium works in Vadheim, Norway, are now in operation and producing metallic sodium. Hiorth made experiments with sodium as a refining agent for iron and steel, by introducing sodium in vapor form into the iron bath from beneath. The experiments were made on a very small scale, however, in crucibles containing 1 kg of charge. The effect of this treatment on the carbon, silicon, sulphur, phosphorus and manganese in the steel is very slight. But the sodium is effective in reducing the oxygen content in the steel quite essentially. Naturally, the heat, thereby developed, tends to render the steel more fusible. While sodium might be considered too expensive for such purposes, a valuable by-product is obtained in the form of sodium peroxide.

Quenching; Troostite, Austenite.—Dr. Carl Benedicks' report refers to four subjects: First, the cooling power of different liquids was studied. The cooling power of mercury was found to be considerably less than that of water, and to approach that of rape oil. The factor which plays the main rôle at the cooling in a liquid is the latent heat of vapor. The specific heat is only of secondary influence. The heat conductivity may be entirely neglected. "The essential condition for a quenching liquid to give effective cooling appears to be: (1) a high latent heat of vapor, and (2) so low a temperature that the vapor bubbles formed at the surface of the metal may be easily condensed in the surrounding liquid." The rate of flow of the liquid has very little influence on the effectiveness of the cooling. The second part of Dr. Benedicks' report deals with photographic registrations of the cooling time which under dif-

ferent circumstances is occupied by a steel specimen in passing the interval 700° to 100° on quenching. The cooling time (the reverse of the cooling speed) for the cylindrical steel specimens used is directly proportional to the mass, but almost independent of the free surface area of the specimen. For quenching experiments, in order to obtain a high cooling velocity, it is, therefore, indispensable to use very small specimens, and to prevent them coming into mutual contact during quenching. The third part of the report deals with troostite, and the author's experiments confirm his theory that troostite is a solid colloidal solution of cementite in iron, or, in other words, a pearlite having ultra-microscopic particles of cementite. The fourth part of the report deals with austenite, and the most important fact brought out here, concerning the preservation of austenite in carbon steel is that it requires a high mechanical pressure. It is for this reason that austenite never occurs in the outer layer of a hardened specimen under ordinary conditions.

Hardness of the Constituents of Iron and Steel.—Mr. H. C. Boynton has determined the hardness of the different constituents of iron and steel, hardness being defined as the power to resist penetration by a rapidly revolving diamond point. Ferrite has about the hardness of fluorite, pearlite is close to that of apatite; sorbite varies between apatite and quartz; troostite in the specimen tested is a little softer than quartz; austenite is about the same as quartz. The second part of Mr. Boynton's report deals with the hardening effect of "cold working" (especially wire drawing) upon the components of iron and steel.

High-Speed Tool Steel.—From Mr. C. A. Edwards' report on the function of chromium and tungsten in high-speed tool steel, it appears that the function of chromium is to impart to the alloys—when cooled from very high temperatures—a high degree of hardness, and increase the resistance to tempering. This result, however, is only possible when the necessary amount of tungsten or molybdenum is present.

Iron, Carbon and Sulphur.—Mr. Donald M. Levy deals with the influence of sulphur, as it affects the relations of carbon and iron. The iron-carbon alloys are essentially an iron-carbide series, and the graphitic system does not separate directly as such, but results from the decomposition of separated or separating carbide, which, though stable when in solution, is readily decomposed when free, and in mass, at high temperatures. Carbon in iron passes into solution only as carbide and separates out as such. In cast irons free from silicon and manganese, sulphur up to 0.8 per cent exists as FeS (melting point upward of 1180° C.). Sulphur lowers the melting point of cast iron, i. e., the temperature of separation of the first constituent to solidify (iron containing about 1.5 per cent carbon in solid solution— austenite) which separates out free from sulphur. The sulphur concentrates in the mother-liquid and separates at a temperature of 1130° C., together with, and as a component of, the austenite-cementite eutectic, forming a triple austenite-cementite-sulphide eutectic, the cementite component being interstratified with a jointed pearlite-sulphide one. The temperature at which this eutectic separates is slightly lowered as the sulphide increases toward 0.8 per cent. With sufficiently prolonged cooling, the components of the eutectic areas tend to ball up and run together; in sulphur-free irons this secondary segregation proceeds with great rapidity at temperatures about 1130° C.; the massive cementite thus produced is decomposed rapidly at these temperatures and grey irons result. The presence of iron sulphide in the eutectic introduces intervening layers, which may partly ball up, but even then leave sulphide films between the cementite crystals; these act as emulsifiers, preventing the coalescence which is a preliminary to the decomposition of the carbide, and the iron tends to remain white.

Iron and Phosphorus.—Mr. B. Saklatwalla reports on the different compounds of iron and phosphorus, their preparation and the investigation of their constitution by thermal and metallographic methods and hardness tests.

Hardened Supersaturated Steels.—Mr. E. Hess reports on the microscopic features of hardened supersaturated steels. He believes Howe's theory to be correct, viz.: that the supersaturated steels at temperatures above the critical range consist of austenite. Austenite is stable above the critical range, but in slow cooling through the critical range it tends to split up into ferrite and cementite. The rate of cooling governs the extent to which this reaction is completed.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

Electric Furnaces.

Induction Furnace.—O. Frick, 893,618, July 21, 1908. Application filed Nov. 16, 1905.

The patent refers to the construction of the cover of the annular melting chamber of an induction furnace. This is rotatably supported so that it is possible to observe all parts of the melting space and to charge the same uniformly through a single or some few openings. The cover consists of a single piece so as to obviate cross-joints, the tightening of which always is connected with great difficulties.

Induction Furnace.—K. A. F. Hiorth, 889,522, June 2, 1908. Application filed Jan. 2, 1908.

The smelting chamber of an induction furnace is made of spiral-shape, so as to consist of several turns. The two ends of the spiral are connected together by "a conductor of solid or liquid material." In the latter case the ends of the inner and of the outer convolutions of the channel are connected together by a depression passing under the intermediate portions of the channel. If connection is made by means of a solid conductor we have a combination of an induction- and electrode-furnace.

Siloxicon Articles.—E. G. Acheson, 895,531, Aug. 11, 1908. Application filed July 2, 1906.

In order to protect crucibles, twyers, brick, muffles and other articles of carbon from destruction at high temperatures in the presence of oxygen or when exposed to molten metals, Mr. Acheson protects them with a coating of highly refractory siloxicon. This prolongs the life and prevents disintegration or destruction. A portion of the carbon on the surface of the articles themselves is utilized in producing the siloxicon coating, so that a homogeneous article is obtained. The carbon or graphite article, after having been formed, is embedded in a mixture of silica and carbon in the proportion of 2 SiO₂ to 5 C and exposed to the proper temperature at which silicon, oxygen and carbon combine to form siloxicon.

Electrolytic Processes.

Electrolytic Production of Hypochlorite.—W. P. Digby, 892,983, July 14, 1908. Application filed Sept. 18, 1906.

In most electrolytic processes for the manufacture of hypochlorite solutions, the anodic and cathodic products are allowed to react in the main body of the electrolyte, with the result that a complete decomposition of the chloride within the electrolyte becomes an impossibility, and "it is rarely that more than one-fourth of the chlorine initially present in the form of chloride becomes converted into available chlorine in hypochlorite form." Mr. Digby, who has paid much attention to hypochlorite processes, endeavors to prevent this waste of unconverted chloride by letting the reaction between anode and cathode products go on in a compartment where one of the products is liberated in nascent condition. A separate porous cell or suitable partition around both the anode and cathode plates may be employed. A very small space is left between the surface of the electrode and the inner side of its porous cell. Water or water containing caustic soda or sodium carbonate is fed into the cathode cells. From the cathode cells this liquor, much enriched by the alkaline products liberated at the cathode, is passed through a suitable cooling arrangement and is led into the anode cell where it is passed along a zig-zag course over the surface of

the anode and between the anode and its cell. Here it absorbs the chlorine gas liberated at the anode, the result being that the caustic alkali solution is decomposed to form hypochlorite, which is led off for use. The anode and cathode may be artificially cooled, for instance, by making them hollow and letting ammonia expand in the same.

Diaphragm.—F. A. Decker, 895,732, Aug. 11, 1908. Application filed Feb. 11, 1905.

The diaphragm, Fig. 1, shows four sections, 1, 2, 3 and 4, of porous earthenware or carbon, "sealed together on the lines 5-5 and 6-6 by means of the registering parallel, angularly arranged grooves or sockets 7-7, having rubber 8 packed and vulcanized therein, and the registering, parallel, angularly arranged grooves or sockets 9-9, having rubber 10 packed and vulcanized therein." The joints are made by clamping the sections firmly together in registration after the corresponding grooves have been packed and then heating the plate. The several sections are provided with the bordering flanges or ribs 1', 2', 3' and 4' for strengthening and spacing the structure, and with the strengthening ribs 1", 2", 3" and 4" joined together so as to support the "thin porous diaphragm body produced preferably by removing part of the original body." If a number of such diaphragms are arranged in parallel position to bring the bordering flanges together in registration, compartments are formed.

Electrodeposition of Copper.—Sherard O. Cowper-Coles, 895,163, Aug. 4, 1908. Application filed May 20, 1907.

Copper having the properties of hard-rolled copper of high tensile strength and free from porosity can be deposited at a rapid rate by revolving the cathode at a peripheral speed of 1500 to 2000 feet per minute when employing a current density of 200 amperes per square foot of cathode surface and an electrolyte containing 12.5 per cent of copper sulphate and 13 per cent of sulphuric acid at a temperature of 40° C. The tensile strength of the copper produced increases with the increase of the speed of rotation of the cathode above 1500 feet per minute.

Chromic Acid from Chromic Sulphate.—G. Adolph and A. Pietzsch, 895,930, Aug. 11, 1908. Application filed April 27, 1907.

The patent refers to the recovery of chromic acid from the liquors containing chromic sulfate which are obtained in the well-known process of oxidizing organic compounds by means of chromic acid. In former electrolytic processes of this kind diaphragm cells were always used, for the reason that no means other than the interposition of a diaphragm between the electrodes were available for protecting the chromic acid formed against the reducing action of the hydrogen set free. The inventors have discovered that such protection is obtained by the presence in the chromic sulphate solution of certain alkaline salts, namely, alkaline sulphates or alkaline acetates and mixtures of both. This effect of their presence in the chromic sulphate solution is due on the one hand to a reduction of the cathodic potential. On the other hand, alkaline bichromate is formed as the main oxidation product and this opposes a greater resistance to the reducing action of the nascent hydro-

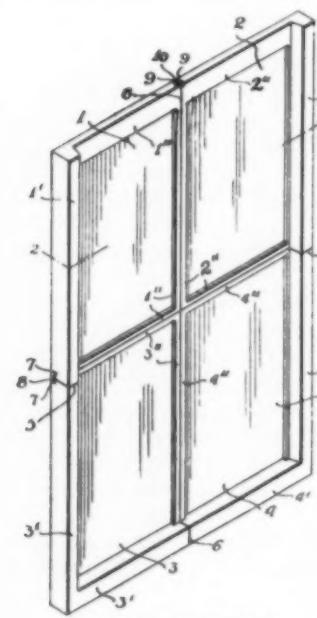


FIG. 1.—DIAPHRAGM.

gen than chromic acid, and, moreover, does not react with free acetic acid and dilute sulphuric acid in the absence of heat. A numerical example is given as follows: "The electrolyte is composed so as to contain 400 grams per liter chromic sulphate ($\text{Cr}_2(\text{SO}_4)_3 + \text{aq}$), 150 grams per liter sodium sulphate ($\text{Na}_2\text{SO}_4 + \text{aq}$), 150 grams per liter sodium acetate ($\text{NaC}_2\text{H}_3\text{O}_2 + \text{aq}$). This liquor is electrolyzed by means of lead electrodes, applying a current density of 200 amperes per square meter at the beginning up to 2000 amperes per square meter, according as the per cent of chromic acid increases in the electrolyte. In this way about 100 grams per liter of chromic acid will be obtained and 90 per cent of the electric current utilized."

Batteries.

Diaphragms.—F. A. Decker. See abstract above under electrolytic processes.

Bromine Battery.—W. Morrison, 892,608, July 7, 1908. Application filed Aug. 11, 1902.

The first claim reads as follows: "In a storage battery, the combination with a cell of non-conducting material, negative and positive elements, the negative element being imperforate, a deposit of bromine supported entirely by the negative element, and means for preventing the deposit of bromine from being displaced from its support."

Bromine Battery.—W. Morrison, 895,600, Aug. 11, 1908. Application filed Aug. 11, 1902.

The first claim reads as follows: "In an electric battery in which bromine is utilized, a cell having a carbon bottom serving as the negative element, the battery being so constructed that the deposit of bromine is held by gravity upon the upper surface of the bottom of the cell, said upper surface being the negative element."

Secondary Battery.—R. J. Fleischer, 888,602, May 26, 1908. Application filed April 8, 1907.

The first claim reads as follows: "A secondary battery comprising a partitioned jar having an upper outer flange below its rim, a cover having a continuous underside groove engaging the rim and a groove engaging each partition, packing in the grooves opposing said rim and partition, and means for holding said cover in detachable connection with said flange."

Storage Battery.—T. A. Willard, 888,951, May 26, 1908. Application filed March 29, 1907.

The first claim refers to "a battery plate consisting of a one-piece blank having rows or stripes of projecting ribs alternating with rows or stripes of flat spaces arranged on opposite faces of the plate and having oval openings arranged crosswise of the ribbed stripes and out of alignment with each other."

Storage Battery.—G. A. Ford, 895,449, Aug. 11, 1908. Application filed Oct. 27, 1905.

The first claim refers to "a storage battery unit consisting of a tray molded from paper pulp having a reinforced upturned marginal flange, a bottom which inclines upward from a central point towards said flange, and integral bosses extending downward from the bottom of said tray, and an electrode in said tray."

Regenerative Battery.—L. P. Basset, 895,715, Aug. 11, 1908. Application filed March 27, 1906.

This invention refers to a double-fluid battery with carbon electrodes, and the essential feature is that the electrolyte resulting from the discharge of the cell can be regenerated simply by heat. The construction of the cell is shown in Fig. 2, representing a vertical and horizontal cross-section. The electrodes, 10, of carbon form a series of compartments, each of which is divided into two parts by a porous partition wall 11. The two groups of compartments, 12 and 13, thus obtained are in communication alternately by branching pipes 7 and 8. In the compartments, 12, the first electrolyte is caused to circulate, composed of sulfuric acid added to a dilute solution of sulfuric acid, and in the second group of compartments, 13, the other electrolyte, composed of bromine and dilute sulfuric

acid. "These two electrolytes come into contact by passing through the porous partition, 11, and react on each other according to the formula,



In this reaction, due to the presence of the porous partitions, an oxidation of the sulfurous acid is produced so as to form sulfuric acid, and the bromine combines with the hydrogen of

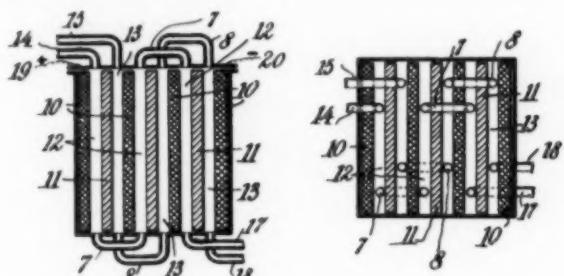


FIG. 2.—REGENERATIVE BATTERY.

the water to form hydrobromic acid. It is this reaction which produces a current of 0.63 volt, which is collected at the terminals 19 and 20." With the aid of a pump the liquid which comes out of the two groups of compartments is forced through a common passage into a suitable heating apparatus or regenerator in which the hydrobromic acid and sulfuric acid are decomposed into bromine, sulfuric acid and water. The two electrolytes above mentioned containing the bromine and the sulfuric acid come out separately from the regenerator, and the course of the operations is continuous.

Discharges Through Gases.

Fixation of Atmospheric Nitrogen.—A. J. Petersson, 889,857, June 2, 1908. Application filed April 13, 1906.

The furnace contains a reaction chamber with a central electrode and a ring-shaped or spiral-shaped (screw-shaped) electrode surrounding the latter. The discharge between the two electrodes takes place radially through the mass of air or gas moving axially. Around the reaction chamber excitation devices are provided for creating in the reaction chamber a magnetic field of axial direction. "By the said arrangement of the electrodes and the magnetic field in relation to each other, it will be possible to obtain the power, by which the arc is placed, proportional or approximately proportional to the length of the path that each part of the arc has to run, whereby the various points of the arc will be displaced at the same angular velocity, thus obviating the risk of the arc being disrupted."

RECENT METALLURGICAL PATENTS.

Zinc.

Zinc Refining.—It has long been known that zinc may be separated from metals of greater specific gravity by reducing the spelter to a molten condition and allowing the heavier metal to settle out. The zinc, under these conditions, may be distilled at a temperature which will not affect the heavier metal, although in practice it is found that the process is frequently accompanied by the distillation of appreciable percentages of the contaminating metal or metals (lead, zinc, etc.). R. Ziesing (893,415, July 14, 1908) overcomes this difficulty by directing heat against the retorts from above, and shielding those portions of the retort containing the lead and silver from any direct heat. The body of contaminating metal thus remains quiescent, while the other portions of the retort are raised to a sufficiently high temperature to maintain rapid distillation of the zinc. The process is carried out in a down-draft furnace, in which the retorts are disposed upon beds or supporting pillars of non-conducting material. Specially formed retorts are employed so

as to retain the bottom portions of their contents in cool condition.

Iron and Steel.

Turbine Furnace.—We have repeatedly pointed out how in Mr. C. G. P. de Laval's inventions—from the big steam turbine to the small cream separator—the rapid rotary movement is of pre-eminent importance. He applies it in his zinc furnace and has suggested it for iron reduction. In a recent patent (885,766, April 28) he proposes to use the same principle to obtain a violent chemical reaction between materials in general. Naturally this is best possible with finely powdered and intimately mixed materials. The furnace for applying this principle is shown in the adjoining illustration. 1 is the cylindrical furnace chamber with the hopper 2 for introduction of the pulverous charge. In the lower part of the furnace is an outlet 3 for the molten charge and a central outlet 4 for the gases of reaction.

Opening into the upper part of the furnace is the contracted mouth of a tangentially arranged pipe or nozzle 5 for air or gas which enters into the furnace with great velocity and rapidly whirls or rotates within the furnace, carrying along with it the pulverous charge introduced through 2. The gas moves in a spiral direction from the circumference to the central line of the furnace toward the exit 4. On the other hand, the charge moves in a spiral direction from the center 2 to the circumference of the furnace. The

application to the extraction of iron is as follows: The charge consists of iron ore, slag forming materials and carbon, which is burnt to CO in the upper part of the furnace. The gas introduced through 5 consists of carbon monoxide or of air, which if desired may be mixed with carbon so as to form carbon monoxide within the furnace. The molten metal and slag are withdrawn through 3. If it is desired to establish an oxidizing zone in the lower part of the furnace a tangentially arranged pipe may be provided below 6, through which air is blown into the furnace so as to burn the CO, formed in the upper part of the furnace, to CO₂.

Thermit Process.

Reduction of Chromium.—In the application of the well-known Goldschmidt aluminothermic method to the production of carbon-free chromium, the oxide Cr₂O₃ has been employed in the past. Its disadvantage is a comparatively small output of chromium due to the slowness of the reaction. If on the other hand a higher oxide of chromium is mixed with aluminium, the reaction is too quick and is rather turbulent and involves danger and loss of metal. According to Hans Goldschmidt and Otto Weil (895,628, August 11, 1908) these disadvantages can be overcome and the output of metal increased by about 30 or 40 per cent, if a small amount of a higher oxide (for example 1 per cent of chromic acid) is added to Cr₂O₃. This addition serves as a stimulant for quicker reaction and at the same time causes the formation of an easily melting slag. A suitable mixture consists of 100 kilograms of pure Cr₂O₃, 3 to 4 kilograms of chromic acid and 34 to 35 kilograms of finely granulated aluminium.

National Waste.

By OSKAR NAGEL, PH.D.

The present industrial depression has caused a widespread pessimism as to the future earning capacity of our industries. Though we all know that we have still immense deposits of minerals, ores and fuels that have hardly been touched, there is a certain uneasiness, because for opening up these deposits capital will be required, which can only be obtained from the profits of the industries already in existence.

Hence it is of the most vital interest to ascertain ways and means of conducting our industrial operations in a more economical way. If we look over our iron, coke and other industries and remember certain improvements which have been in successful use in Europe for the last eight to ten years, we will have no difficulty in arriving at some valuable conclusions.

All industries are based upon the consumption of fuel, and since our coal deposits are by no means unlimited, it is obvious that fuel economy is of the greatest importance to the nation. Hence we will first consider the waste of fuel in our main industries and the methods to prevent this waste.

According to the census of manufactures about 16,000,000 tons of pig iron were produced in the United States in 1905 in blast furnaces in which heated air (hot blast) is blown through the ore, coke and limestone, contained in the furnace in alternate layers. In this process the air, by going through the charge, is transformed into a combustible gas, called blast furnace gas, which leaves the furnace at the top.

A very large part of this valuable gas, which is well adapted for fuel purposes and exceedingly fit for driving gas engines, is going to waste in the United States, while in Europe every bit of it is utilized. From the 16,000,000 tons of pig iron produced, about 225,000,000,000 cubic feet of blast furnace gas are obtained, half of this quantity being used for heating the air blast. Of the other half hardly one-third is used, the rest going to waste. If we express this waste in horsepowers that could be generated by its combustion in gas engines, we find that over 800,000 horsepowers are continuously wasted for 24 hours of every day in the year. According to the price asked at Niagara Falls for one horsepower per year, which is \$15, this "wasted rest" is equivalent to a yearly loss of \$12,000,000. Even according to the lowest cost that waterpower can be produced for under most advantageous conditions (in Norway), which is \$5 per horsepower per year, the annual loss amounts to \$4,000,000. A first start for utilizing this waste gas in the United States was made a few years ago by the Lackawanna Steel Company, and now the United States Steel Corporation is taking steps in the same direction, but still it will be many years before we will completely do away with this waste.

The coke industry affords another instance of wasteful operation. The manufacture of coke is very similar to the manufacture of illuminating gas (coal gas); in the latter coke is obtained as a by-product of the gas manufacture, while in the former gas is obtained as a by-product of the coke-making. In Europe nearly all the coke-oven gas produced is utilized, while in this country 90 per cent. escapes into the air as a waste. According to the Mineral Resources of 1905, the gas obtained in the manufacture of 32,000,000 tons of coke was wasted. This quantity of gas is sufficient to continuously develop 700,000 horsepowers throughout the year and hence has a fair value of \$10,500,000 and a minimum value of \$3,500,000. We now see that the combined iron and coke industries are wasting continuously at least 1,500,000 horsepowers in a manner which forever prevents the reclamation of this waste and hastens the exhaustion of our coal deposits.

A similar waste of fuel prevails in the smaller industries. I know of power plants owned by large and wealthy corporations in which 7 to 10 pounds of coal are burned to produce one horsepower per hour, while not more than 3 pounds should be consumed in a good steam plant. This shows that by using modern machinery the drain upon our coal mines will be con-

siderably reduced. According to the results of modern engineering science the use of steam power is extremely wasteful, if the heat of the exhaust steam is not or cannot be utilized.

Hence for such installations in which power is to be produced exclusively, the gas engine in connection with the so-called gas producer is the most economical means for developing power, one horsepower being produced by this system for one hour from one pound of coal. The gas producer is an ordinary stove containing a high layer of incandescent fuel, which is transformed by the air drawn through into a combustible gas called producer-gas. The manufacture of this gas is chemically nearly identical with the gas formation in the blast furnace, the latter being, in fact, a huge gas producer.

We are wasting fuel in an incredible manner. We allow power equivalent to the capacity of several Niagara Falls to escape into the air, while we see that the European nations are utilizing the fuel three times as economically as we do and are successfully using such low-grade materials as lignite and peat, which we do not seem to want to touch before we have to.

Another national waste, and undoubtedly the worst and most dangerous, is the reckless drain upon our forests. It is our fault that wood is getting scarcer and more expensive every year. According to a report of the Department of Agriculture the estimates of standing timber range roughly from 1400 to 2000 billion ft. Assuming a stumpage of 1400 billion ft., an annual use of 100 billion ft., and neglecting growth in the calculation, the exhaustion of our timber supply is indicated in 14 years. Assuming the same use and stand, with an annual growth of 40 billion ft., we have a supply for 23 years. Assuming an annual use of 150 billion ft., the first supposition becomes 9 years and the second 13 years. Assuming a stand of 2000 billion ft., a use of 100 billion ft., and neglecting growth, we have 20 years' supply. Assuming the same conditions, with an annual growth of 40 billion ft., we have 33 years' supply. With an annual use of 150 billion ft., these estimates become, respectively, 13 and 18 years.

As, considering the drain upon our forests, the annual consumption of wood is probably three times the annual growth, it is evident that something has to be done for increasing the yield of our forests. For this purpose the principles of forestry have to be applied, which rest on natural laws.

Let us see what forestry has done in Germany. Starting with forests, which were in as bad shape as many of our own, which had been recklessly cut over, it raised the average yield of wood per acre from 20 cu. ft. in 1830 to 65 cu. ft. in 1904. During the same period of time it trebled the proportion of saw timber got from the average cut, which means, in other words, that through the practice of forestry the timber lands of Germany are of three times better quality to-day than when no system was used. And in 54 years it increased the money returns from an average acre of forest sevenfold. Yet to-day the forests are in better condition than ever before, and under the present system of management it is possible for the German forester to say with absolute certainty that the high yield and large returns which the forests now give will be continued indefinitely into the future.

There are many other products that go to waste as, for instance, the garbage of our cities. The utilization of the blood in our stock yards is extremely crude, while in Europe a very valuable product, blood albumen, is extracted from the blood. The utilization of our various ores and minerals is also far from reaching the European economy.

Up to this time our engineers were mainly striving for a reduction of the cost of production by replacing manual work by machine work. Immense savings have thereby been effected and America has become the leading industrial country. For retaining this position it is imperative to also consider all possible savings that can be made in raw materials. By means of our ingenious mechanical appliances we are enabled to fully utilize the capacity of our workingmen. It is now about time that we also utilize our raw materials in a scientific way.

Mercury Ammeter for Large Currents

Considerable difficulty is experienced in making exact measurements of strong alternating currents, considerably exceeding 1,000 amperes, such as are used in electric furnaces for electric welding, etc.

In practice, these large currents are measured with the aid of a series transformer. The ratio of the transformer is computed and its small secondary current is measured by an alter-

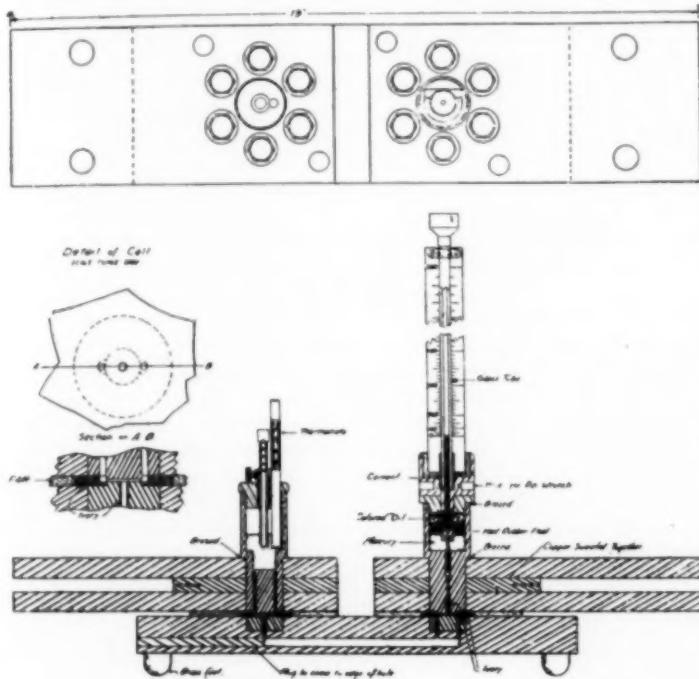


FIG. 1.—SECTIONS OF MERCURY AMMETER.

nating-current ammeter which has been accurately checked by any of the well-known methods. The large primary current is then known as accurately as the calculated ratio of transformation of the series transformer.

A true and accurate value of the ratio of a series transformer cannot, however, be obtained by computation. The ratio should be obtained experimentally, under the conditions of frequency, wave form and load, in which the transformer is to be used to get an accurate determination of the heavy primary current from a precise measurement of the small secondary current.

There is, therefore, need of a standardization instrument, of not excessive cost, which can be inserted directly in an alternating-current circuit, carrying any current over 1,000 amperes, and which will measure this current with the same precision as small alternating currents are measured. The first simple and inexpensive instrument which answers this purpose is the mercury ammeter designed by Dr. E. F. Northrup and described by him in a Franklin Institute paper (which may be found in full in the August issue of the *Journal* of this Institute). The instrument is of special interest to the readers of this journal since in principle it is based on the "pinch effect" which was first discovered by Carl Hering (this journal, Vol. V, page 223), while its theory was fully worked out and various applications made of it by Dr. Northrup himself (*Phys. Rev.*, July, 1907).

The adjoining illustration shows a mercury ammeter suitable for measuring 2,000 amperes alternating current. The action of the instrument depends upon the essential principle that when a current, direct or alternating, passes through a conductor, there is set up in the conductor an attraction towards its axis of all the imaginary elemental filaments of the conductor. This attraction, when the conductor is a liquid conductor suitably confined in an insulting tubular space, results

in a difference of hydrostatic pressure between the axis and the circumference of the conductor. This difference in pressure in a conductor of circular cross-section is numerically equal to the square of the current strength and inversely equal to the cross-sectional area of the conductor.

If the conductor is made up of two or more liquid portions in circuit with solid portions the differences in pressure set up by the passage of the current in the liquid portions may be added, like electromotive forces, in series and the resultant pressure difference utilized to raise a column of liquid. This raised liquid column may be used to directly measure the value of the current, or the motion of the raising column can be communicated to any style of pointer moving over a scale or dial.

The liquid found to be best adapted to use in the construction is mercury. The height to which the mercury column will rise with a given current may be magnified for convenience of observation, but not for accuracy, by causing the pressure to be transferred to a column of colored water. Further description of the mechanical features of the apparatus is made unnecessary in view of the accompanying illustrations.

In practice it is found necessary to use two mercury pockets or cells and to make these but 1/64th of an inch in their axial dimension. On account of their short length and the proximity of massive copper blocks to rapidly conduct away the heat, great current densities may be passed through the cells. In fact 20,000 amperes to the square inch gave a rise in temperature in the cell as measured by a thermo-couple of only 16° C.

Mercury has sixty times the resistance of copper, and hence, if this latter metal were to replace the mercury, current densities of 1,200,000 amperes per square inch under like conditions could be passed through the short conductor. It may also be shown that keeping the axial length of the cells always the same, the number of watts required to raise a column of water a given height is independent of the number of mercury cells used and the current passing.

It is found that approximately 1.4 watts is required for every inch rise of water. Hence, as an ammeter properly constructed

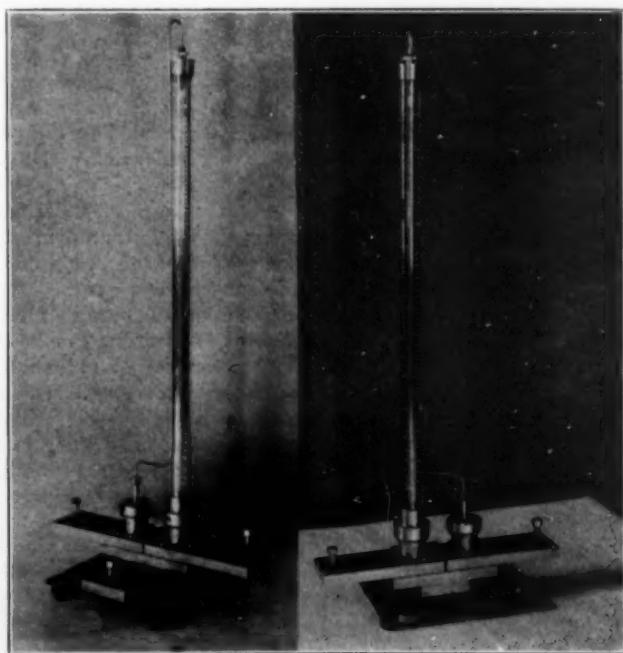


FIG. 2.—MERCURY AMMETER.

can be easily made to dissipate 35 watts, it can be made to give a scale, using water, 25 inches high.

When, however, water is used, the instrument has a temperature error of $\frac{1}{8}$ per cent per 10° C., as this represents the in-

crease in the lightness of the water which expends one part in four thousand for every degree Centigrade. For precision work the error may be calculated and allowed for, as the temperature is easily measured. If water is not used the rise in the mercury column may be directly observed with a cathetometer or microscope, in which case the possible precision is very high.

The indications are absolutely the same with direct and alternating currents and strictly follow the square law. It is proposed to carefully construct a large mercury ammeter with all its dimensions carefully measured and to employ it in the absolute determination of current.

The mercury ammeter may, if desired, have its constants obtained at one point on the scale by passing a large known storage-battery current through it; the remainder of the scale may then be laid off by calculation and the instrument is then adapted to give precise measurements of large alternating currents. By inserting this instrument in series with the primary of a series transformer of large capacity to measure the primary current and by measuring at the same time the secondary current with the A.C.-D.C. Comparator, or any instrument which has been checked by it, the ratio becomes accurately and experimentally determined. The series transformer with its constants determined in this manner becomes then a truly valuable adjunct in the measurement of large alternating currents. It only remains to determine the phase relations existing between the primary and secondary currents of the transformer to make of it a precision piece of apparatus.

The useful lower range of the mercury ammeter has not yet been fully determined, but though a 500-ampere instrument is easy to construct, there would be little demand for instruments of similar capacity, as below this precise null methods are available.

Fig. 2 gives two outside views of a mercury ammeter which reads from 300 to 1,400 amperes without using less than one-fifth of the scale at any time. The two photographs are two views of the same instrument. The right-hand photograph is a front view of the instrument and the left-hand photograph is a back view of the instrument.

In the latter it will be noted that there are three terminals. When connection is made to the two end terminals, the two cells of the instrument are thrown in series and give a scale of one value. When the left-hand terminal and the middle one are connected, but one cell is used giving a scale of another value. When the right-hand terminal and the middle one are connected, a third scale is obtained having still another value, the two cells being of unequal size.

In this way the instrument may give a number of scales in the same manner as a current dynamometer may give a number of scales by having different windings of the fixed coil which can be connected in by joining to different binding posts.

The small metal tube reaching from the top of the scale tube to one of the cells is an improvement made since the Franklin Institute paper was written, serving the purpose of excluding the external air and preventing the colored water, used in the instrument, from evaporating.

The Leeds & Northrup Co., of Philadelphia, build these instruments to order if the minimum current required to be measured is not too small, say 500 amperes. The maximum current that can be measured with this instrument may be anything.

This instrument, being based in an ingenious way on a new principle, represents certainly one of the most interesting developments in electrical instrument design and should prove very useful especially in the hands of electrochemists and electrometallurgists.

Disinfecting Liquid.

Electrolytic production of hypochlorite solutions for disinfecting purposes is old and well known. While various com-

mercial attempts made in this country have not led to a permanent installation, much interest has been taken in England in recent years in processes of this kind, and we have had occasion to refer repeatedly especially to the Hermite process. Thanks to the efforts of the Medical Officer of Health its use has been largely developed in the Metropolitan Borough of Poplar, where it is prepared by a private plant, and it has also been employed at many other large establishments in England, among them the Royal Military Hospital at Netley.

According to the London *Electrician* of July 31 a commercial plant for manufacturing this disinfecting fluid has been erected. This solution is called "Thalassol," to suggest the possibility of making it from sea water (thalassa being the Greek word for Ocean). In practice, however, an artificial solution of magnesium and sodium chlorides is used, since it is exceedingly cheap to prepare and it is free from organic matter. Further, if sea water is used the solution obtained is not always of uniform strength.

The cells in which electrolysis takes place contain electrodes of zinc and platinum, arranged in tiers so that the electrolyte can flow over them. In this particular case 40 cells are arranged in series, and the necessary current is supplied from a small motor-generator coupled to the supply company's mains.

According to a Faraday Society paper of Biggs, the electrolytic process "consists in the electrolysis of the magnesium chloride solution, the sodium chloride acting simply as a carrier, hydroxide of magnesium and chlorine being the products. It is stated that the latter combines with the oxygen of the water to form oxides of chlorine, which constitute the vehicle for the bleaching action, and not merely hypochlorite. To the solution thus formed is added a special alkali, and is transferred to carboys with repeated stirring."

Thalassol is non-poisonous and is sold in ordinary bottles. In spite of the fact that it contains chlorine when quiescent, it is nearly odorless and quite pleasant to smell. It gives off chlorine when in action, especially when attacking organic matter. In certain parts of England it is said to have become quite a household article, being used for such wide-apart objects as brushing the teeth and washing the floors. It is a great advantage in laundry work and is said to be excellent for removing stains.

What a Manufacturer Should Know About Coal.

At the annual meeting of the National Association of Cotton Manufacturers in Boston, Mr. E. G. BAILEY discussed "some things a manufacturer should know about coal." This address has been published as No. 3 of the serial of professional papers of members of the staff of the Arthur D. Little Laboratory of 93 Broad Street, Boston.

The manufacturer should first consider where he can always get coal when he needs it. There is a possibility of strikes or of delays in transportation and in placing a contract this point should be kept in mind and whenever the difference in price is not too great, preference should be given to the company that is most able to keep its customers supplied with coal at such exceptional times.

If the plant is at a great distance from the mine, storage of coal becomes necessary and this involves considerable expense. There are many theories as to the cause of spontaneous combustion in coal piles and several remedies have been tried with more or less success. It seems that the rate of circulation of air through a coal pile has more to do with this question than any other condition outside of the character of the coal.

Other important points which a manufacturer should consider are where he can get coal of such character and quality that his plant will not be crippled for lack of steam and further what coal is the most economical for him to burn.

Coal varies more in character and quality than any other mineral produced. In character it is found in all successive

stages between lignite and anthracite. Each different kind is more applicable for one purpose than another.

In selecting a coal for making illuminating gas the illumination obtained from the gas measured in "candle feet" is of primary importance, while the coke and tar are by-products, and sulphur is the impurity that causes additional expense.

For making coke the purity, structure and yield of coke are the properties to be considered, and the gas, tar and ammonia may be utilized as by-products.

In buying steam coal the amount of heat that may be developed from it is the measure of its value to you. There is no byproduct that may be utilized, except that in some cases the scale of ashes might be considered in this connection, but their removal is generally an additional expense. Two coals at the same price and containing the same number of heat units may not be equally desirable. The difference in volatile matter might cause the lower to prove more satisfactory under certain conditions of smoke restriction, while the higher volatile coal would probably be more applicable in a plant with fluctuating load. The amount and nature of ash in regard to the formation of clinker often needs to be considered.

The liability of spontaneous combustion of one coal more than another may make it advisable to pay several cents per ton more for one coal containing no more heat units than the other.

The following table shows the analyses and results of evaporative tests of some of the better coals together with their price f. o. b. cars at the plant of the inland New England mill. The relative values have been calculated by taking coal A as a basis and determining what will be the cost of the equivalent amount of coal required to produce the same number of heat units as coal A produces for \$4.60 per ton. For example, should one buy coal F at \$4.40 per ton the coal bill would amount to the same as if he had bought coal A and paid \$4.92 per ton for it, but as he can get coal A for \$4.60 you would save 32 cents per ton by taking coal A instead of coal F at the given prices.

In this case it appears that neither the best nor the lowest priced coal would be the cheapest to buy.

Mois. Coal. ture.	Vola- tile, tle.	car- bon.	Sul- phur.	Lbs. water evapor- ated from and at 212° F.	Relative cost per ton with Coal A as basis		By evap- oration.		
					B. t. u.	f. o. b.			
A	1.25	17.94	73.15	7.66 2.07	14,354	9.93	\$4.60	\$4.60	\$4.60
B	1.43	17.59	71.58	9.40 1.09	14,032	9.73	4.55	4.65	4.64
C	1.17	30.51	61.01	7.31 0.99	14,251	9.79	4.65	4.69	4.71
D	1.36	16.42	71.35	10.87 1.77	13,511	9.60	4.58	4.76	4.74
E	1.75	19.58	71.95	6.72 0.84	14,533	10.03	4.86	4.80	4.79
F	3.72	21.06	66.90	8.32 1.36	12,834	8.80	4.40	4.92	4.96
G	1.74	31.16	53.68	13.42 2.93	12,833	8.67	4.60	5.14	5.27

In this table the coals are arranged in order of cost for equal amounts of heat generated and equal evaporation, but in selecting a coal for any particular plant it might be policy to select a coal that would cost a little more money in order to obtain some particular advantage that a certain coal might have over another.

Comparing coals A and B, coal A appears to be better in every way except that it contains about 1 per cent more sulphur than does B. For steam purposes the sulphur is of little importance below 2 per cent, at least, so that coal A would probably be selected on account of its being 5 cents per ton cheaper on a heat-unit basis and there would also be less ash to handle.

In case a plant had limited draft and boiler capacity a coal like C might be selected in preference to B, or even A, with a difference of 9 cents per ton in favor of coal A.

Should the prevention of smoke be an item of considerable importance, coal D would probably be purchased at an additional expense of 7 cents per ton, as compared with coal C. Of the two coals D and E there is a difference of only 4 cents per ton and that would scarcely pay for the additional cost of handling ashes, the possibility of not being able to carry the load without the use of more boilers, and other expenses that are greater with a poorer coal.

While coal E is the best all round coal, it would pay to pur-

chase it, while coal A could be obtained for 20 cents per ton cheaper on a heat-unit basis, and 19 cents per ton cheaper on an evaporation basis.

Coals F and G are both much inferior to the others and their purchase would not be considered when any of the other coals were available at the given prices. Judging from the ash and sulphur alone, it would seem that coal F would be better than either B or D, but a certain characteristic appears in this coal that makes it different from any of the others. It is "crop" or "red" coal coming from a part of the seam near the outcrop and has become saturated with the surface that has been percolating through it for hundreds of years.

The moisture is much higher than in any of the other coals and it contains a still larger percentage of combined water that is not driven off by the mere drying of the coal. If a man were depending upon the ash determination alone he would never detect that he was receiving an inferior quality of coal; in comparison with coal A he would be paying 20 cents per ton less for the coal, yet he would have to burn so much more of it to develop the same horse-power that he would actually be losing 32 cents per ton, or \$16,000 per year on a 50,000-ton contract.

Coal G is high in ash and sulphur and correspondingly low in B.t.u., so that it would be a very expensive fuel to burn at the price quoted, and in comparison with the other coal it should not be considered. Yet there are thousands of tons of it being burned and the manufacturer seems to be willing to pay the price.

In the preceding table the equivalent evaporation in pounds of water from and at 212 deg. Fahr. is given as determined in carefully conducted boiler tests on the same boiler. They represent the average of two or more tests under as nearly identical conditions as it is possible to maintain, thus accounting for the closeness of their comparisons with the B.t.u. determination. Duplicate boiler tests on the same coal frequently vary 5 to 10 per cent, even though the method of firing and the rate of combustion have changed as little as possible.

The chemical analysis and calorimetric determination will represent the value of coal within 1 per cent, providing the samples are properly taken. The plea for evaporation tests because they are practical is counterbalanced by their failure to burn the coal under equally comparable conditions in two or more cases. A fireman must become accustomed to different coals and find wherein they must be handled differently in the firebox in order to obtain the best evaporation from each. The laboratory tests are generally considered as theoretical and unreliable. But theory and practice always agree when they both represent the facts.

After the most economical coal has been sold it remains for the manufacturer to see that this coal is delivered. If the coal company knows that the coal is being systematically analyzed by their customer, this fact is generally sufficient to ensure delivery of coal of uniform quality.

Finally, the manufacturer has to consider how to convert as large a portion as possible of the energy of the coal into useful work. The question of smoke prevention must receive more consideration from the manufacturer in the future than it has in the past.

After combustion has taken place the heat of the coal appears in the form of sensible heat in the gases leaving the furnace or combustion chamber. The important problem is to cool the gases as much as possible with a minimum of boiler heating surface. In order to accomplish this the heating surface should be kept clean inside and out. Too much emphasis cannot be put on this point.

Combustion is more complete with considerable excess air, but this excess air passing through the furnace reduces the temperature of the gases approaching the boiler and the temperature of the escaping gases remains about the same so that a larger percentage of the developed heat is lost up the stack. This condition might be compared with a steam engine running

with low initial pressure and exhausting against a high back pressure.

The amount of air excess is regulated by the intensity of draft and condition of the bed of fuel. Few firemen have ever had the opportunity of learning what was the best thickness of fire or intensity of draft under certain kind of coal. Many people think the stronger the draft the better, but there is opportunity to save thousands of dollars every year in many plants by merely reducing the draft or by better regulation of it. The installation of a damper regulator is not always the remedy, for they often cause more loss than occurred when hand-regulated dampers were used.

The analysis of the flue gases is the best criterion for regulating the conditions of a furnace so as to obtain nearly complete combustion with a minimum of air excess. The perfecting of automatic gas indicators and recorders will do very much toward increasing the boiler-room efficiency.

No one kind of boilers or heat-absorbing apparatus will give equal satisfaction in all plants. This depends upon location of plant, kind of water, uniformity of load, kind of coal, etc., and must be determined in each individual case.

Refined Copper.

According to a recent press bulletin of the U. S. Geological Survey the production in 1907 of refined new copper of domestic origin was 784,271,427 pounds, a decrease of 103,410,960 pounds, or 13.2 per cent, from the production of 1906. The total output of refined copper (exclusive of domestic scrap, etc.) by domestic refineries in 1907 was 1,032,516,247 pounds.

In addition to this production of refined copper 25,129,617 pounds were recovered during the year by the regular copper-refining companies of the country from domestic scrap, drosses, etc., and returns from practically all the known refiners of secondary materials indicate that 35,355,966 pounds additional were turned out by them as casting copper and in alloys. The copper produced from secondary sources in 1907 was therefore somewhat in excess of 60,000,000 pounds, or more than 7.5 per cent of the year's production of refined new copper.

Returns from all the Lake and electrolytic refiners are practically complete and show the following stocks of refined copper on hand at the beginning and end of the year:

	Pounds.
January 1, 1908.....	125,745,796
January 1, 1907.....	46,497,181

Increase during 1907..... 79,248,615

Undelivered sales are almost entirely excluded from these figures, and stocks carried by consumers and brokers have not been estimated. In addition to these stocks of refined copper there were at the smelters, in transit to the refineries, and at the refineries blister copper and material in process of refining to the amount of 135,310,239 pounds on January 1, 1907, and 175,254,659 pounds on January 1, 1908.

The apparent consumption of refined new copper in the United States in 1907 was about 485,000,000 pounds, as compared with 685,000,000 pounds in 1906, and it is probable that in addition most or all of the 60,000,000 pounds of reworked copper was consumed.

The figures given above are compiled by Mr. Graton from the exact records of all but one known producing company. A comprehensive report on the copper industry in 1907 is in preparation and will be published by the Geological Survey as an advance chapter from "Mineral Resources of the United States, Calendar Year 1907."

Tilting Crucible Furnace.

A new tilting crucible furnace has just been placed on the market by the Rockwell Furnace Company of New York City embodying some decidedly advantageous features, which will

be readily appreciated by the foundryman. As can be seen from the illustrations, the crucible is not removed while pouring the metal from the furnace, but remains fixed and the metal is transferred to the moulds by means of a heated ladle or crucible, as preferred.

The burner, which is operated with a fan blast of but 12 ounces, makes but little noise and uses either oil or gas fuel, being located at the top of the heating chamber and the flame is projected down against the bottom of chamber and not against the crucible, which insures a long life of the same. In case of the crucible breaking the metal is all retained in the furnace and does not run on the floor and the melting may be continued until the metal is at the proper temperature, when it may be transferred to the moulds in the usual way. This feature makes it unnecessary for the foundryman to worry when the crucible becomes thin, or to throw it away before it actually breaks, as is often done, when several heats may still be gotten from it.

As any air pressure from 12 ounces to 2 pounds may be

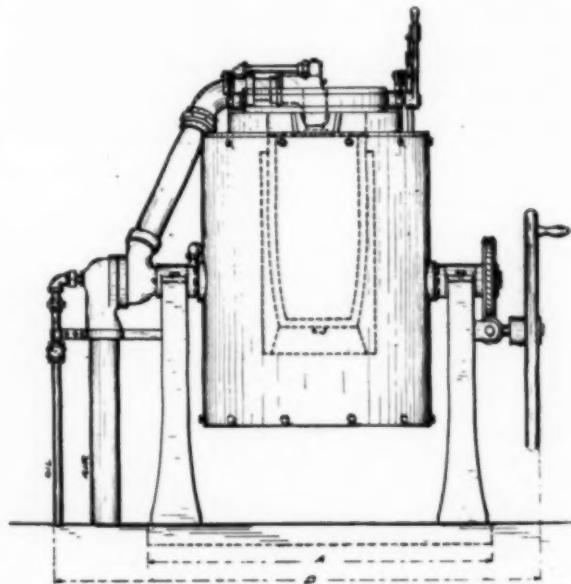


FIG. 1.—SECTION OF TILTING FURNACE.

used, the furnace can be operated from any available air and oil system which may be supplying other furnaces, a separate plant being unnecessary.

The cover is manipulated by a lever conveniently located at the rear of the furnace, from which a pin engages a ratchet and holds the door rigidly in any required position and permits covering the crucible after pouring without returning the furnace to an upright position.

Heavy pieces of metal may be fed to the crucible through the opening in the cover of the furnace while the blast is on. The waste heat passing through melts it down into the crucible very rapidly.

As the crucible is not removed, after the first heat metal is always charged into a hot pot, which greatly facilitates the melting.

Where it is essential that the heated gases in the furnace should not come in contact with the metal, a cover may be put on the crucible to protect same. Although it is unnecessary for ordinary work, as scrap yellow brass stampings from the ends of safety pins have been melted hot enough for pouring very light castings with a loss of but 3 per cent. The only precaution taken while melting was to cover the metal with a few pieces of hard coal.

The number of heats per day will vary from 3 to 10, and the amount of fuel required will range from 1½ to 3 gallons.

of oil—210 to 420 cu. ft. natural gas; 315 to 630 cu. ft. illuminating gas; 675 to 1350 cu. ft. 300-B.t.u. water gas, according to the quantity and quality of metal melted, the heat at which the metal is required, and the attention and promptness with



FIG. 2.—TILTING CRUCIBLE FURNACE.

which it is melted and poured. But the above is a fair average.

The furnace is easily relined with simple and inexpensive fire tile.

The furnaces are at present made in four sizes to hold numbers 70, 125, 275 and 450 crucibles respectively. A 32-page catalogue describing this and twenty other styles of melting furnaces has just been issued and may be had from the manufacturers, Rockwell Furnace Co., 26 Cortlandt St., New York.

Screen for Wet Products.

The Traylor Engineering Company, of New York City, have perfected and are manufacturing a new screen for handling fine wet products, which is shown in the adjoining illustration.

The screen surface is octagonal in form, the width of the drum being about 24 in. Each of the eight sections is 18 in. wide in the other direction. The screen cloth is secured to the wooden frames, which are placed in the steel flanges of the drum. An angle is placed over adjoining edges and this is clamped down by means of a key at each end of the angle, as indicated. By this means the frame is very quickly and easily removed and replaced when it is required to change a cloth by merely driving out the keys.

The product to be screened is fed over two distributors provided with fingers for evenly spreading same over the width of the screen; this gives a much more efficient classification than if but one were used.

Each of the screen sections has a compartment in the screen frame running toward the center. The center of this drum is conical, the cone surface sloping outwardly, so that the through product will run out from the drum to the discharge hopper placed on the side of the housing away from the gears. The oversize product remaining on the outside of the screens will, as the drum rotates, fall off into the screen housing in a measure. To effectually clean the meshes of the screen cloth from this oversize material, water spray pipes are provided, each of the eight compartments being furnished with an individual spray pipe, which is connected through the hollow shaft by means of a swivel coupling at its outward end to the water supply. Each of the eight pipes rotating to

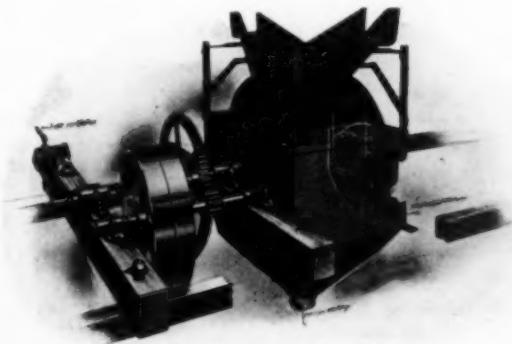
their respective compartments are provided with an automatic valve. These valves are tripped by a cam so that as each compartment nears the bottom position in the revolution of the drum the valve will be tripped. The spray pipe in each of these compartments is perforated so that the entire surface of the screen will be flooded during the time the water is turned on. This connection is so arranged that as each successive compartment of the screen approaches the bottom position in revolution, this flooding takes place and effectually clears the meshes of the cloth of all oversize material.

In order to protect the spray openings from being clogged, a gravity hood or swinging saddle is placed on each pipe. This is weighted so that the angle guard of same is likewise vertical above the pipe and thus prevents the screened product from falling into openings of the spray pipe and clogging the same. As these pipes approach the bottom position where spraying takes place, such angle guards being above the pipe do not obstruct the spray.

The housing of the screen is tapered to a central discharge outlet for the oversize product, and the service of this water used for spraying is very desirable inasmuch as it performs the duty of conveying the oversize products in the launder after leaving the screen, as well as the duty performed in washing the meshes of the screen clear.

The machine takes practically no power to drive it, inasmuch as the weight of the oversize product tends to assist in the rotation of the same. The entire machine is exceedingly simple and when properly set up requires no further special attention for its operation.

Another principal feature of the machine is that it is noise-



SCREEN FOR WET PRODUCTS.

less and revolves slowly at about eight revolutions per minute. The wear and tear is practically nil, except the natural wear of the action of the ore on the screen cloth.

Notes.

The Brown Hoisting Machinery Company of Cleveland have sent us their Catalog O, illustrating and describing their machinery for use about gas plants, for the handling of coal, coke, etc.

The Moechel & Lowther Engineering Company of Kansas City, Mo., have established a consulting office and testing laboratory for chemical engineering and industrial engineering work at 1110 and 1112 Wyandotte Street, Kansas City, Mo.

The Wilson-Maeulen Company have reopened a New York City office and exhibition room at 1 East Forty-second Street where their newest apparatus for the measurement and recording of high temperatures may be seen. Coincident with their return to this city, it is announced that Mr. C. H. Wilson is now the sole owner of the business, having purchased the interest of his former partner, Mr. Frederick Maeulen. The business will continue under the old name of Wilson-Maeulen Co., and their most popular line of low-resistance thermoelec-

tric pyrometers will still be known as the "Advance Electric Pyrometers."

Cyanide Plants.—The Pacific Tank Company, of San Francisco, have sent us their new mining and cyaniding catalog, known as Catalog 7. The company makes a specialty of complete cyanide plants, tanks, mining and mill supplies. The catalog is well gotten up and nicely illustrated and contains many tables and information useful to the cyanide engineer.

The Bureau of Standards in Washington, have just issued a revised edition of their regulations on the testing of glass volumetric apparatus. The attention of chemists should be called to the fact that certain essential changes have been made in the regulations previously published. Copies of the new edition may be obtained free upon application to the bureau.

Seventeen Years of Experimental Research and Development.—On the occasion of the presentation of the Rumford medal to Mr. Edward G. Acheson for his electric furnace products, Mr. Acheson delivered to the American Academy of Arts and Sciences, in Boston, a very interesting review of his electric-furnace work on carborundum, graphite, silicon and siloxicon, and then dealt especially with his researches on colloidal or deflocculated graphite. This lecture has just been issued in form of a very neat illustrated pamphlet.

Solderless Cable Joint.—Messrs. Dossert & Company, 242 West Forty-first Street, New York, have just issued an illustrated pamphlet on the Dossert solderless electrical connectors or cable joints for stranded or solid wire. This mechanical joint should be of special interest for electric-furnace conductors and electrolytic tank connections. This joint is naturally not affected at all by heat. It has the further advantage that when once made, it is absolutely permanent, but that it can be easily disconnected when so desired.

The American Gröndal Kjellin Company of New York City have sent us two well-illustrated pamphlets, one dealing with the Gröndal charcoal kiln, the other with the Gröndal processes of concentration and briquetting iron ores. The charcoal kiln we intend to describe in a future issue. Concerning the concentration and briquetting of iron ores, see the paper by Mr. P. McN. Bennie on page 134 of our Vol. V.

The American Manganese Bronze Company has recently been formed with offices at 99 John Street, New York, and works at Holmesburg, near Philadelphia, Pa. Mr. Charles R. Spare, formerly chemist with Cramps Ship Yards, Philadelphia, is the general manager, and several of the main products of the company will be known by his name, namely, Spare's manganese bronze, Spare's white bronze and Spare's hydraulic bronze. In addition the company will manufacture United States government alloys, and will specialize on marine hydraulic work and high-power machinery.

Aluminium Castings.—Very favorable results have been obtained in service from castings manufactured from aluminium-magnesium alloy. The castings containing 8 to 10 per cent pure magnesium are about 15 per cent lighter than the aluminium-copper alloy and also about 33 per cent stronger. Recent experiments made in the machining of castings made of aluminium and magnesium showed that the castings machined 75 per cent faster than those which are made of the alloy of aluminium and copper. In order to get the best result it is necessary to use the purest grade of magnesium metal. This, another product of electrochemistry, is now on the market. We are obliged to Messrs. C. W. Leavitt & Company, of New York City, for sending us a sample bar of pure magnesium metal.

The American Blower Company of Detroit have issued a new edition of their engine catalog in which they have included a number of new sizes recently placed on the market.

The Moore Filter Company have closed a contract with the San Rafael mine, of Pachuca, Mexico, of which Sr. Edmundo Girault is manager, and Mr. J. B. Empston is consulting engineer, for a type A filter plant of a daily capacity of 250 tons.

It is proposed to double the capacity just as soon as the first unit is in operation.

Cyanide Process.—To all interested in gold metallurgy, the cyanide catalog, just issued by the Colorado Iron Works Company, of Denver, should be welcome, as it contains a concise and well-written outline of the cyanide process, its history and technique, besides fully illustrated descriptions of all kinds of machinery required in cyanide plants. The catalog contains many useful data for the practice, like table of tank capacities on page 93. The catalog bears the earmarks of careful and original preparation.

The Rockwell Furnace Company of New York City, have just issued a well-illustrated pamphlet on their portable heaters for oil fuel. They are intended for heating work which is too bulky or inconvenient to remove to a furnace, and where it is desirable to take the heater to the work, as is the case with annealing, hardening, expanding, bending, brazing, skin drying, lead melting and rivet heating. A descriptive article on this process may be found on page 85 of our February issue.

Messrs. Waller & Renaud, chemical engineers, 159 Front Street, New York City, have sent us a little pamphlet containing an article by H. S. Renaud on coal-pile extravagance, which is well worth the attention of coal buyers. The author quotes W. L. Abbott as follows: "The greatest possibilities for saving or wasting about a steam plant are undoubtedly in the coal pile, but as it is a dirty proposition and many of its features not well understood, the subject does not receive the consideration to which it is entitled." Mr. Renaud urges emphatically to contract for coal on specifications and analysis, and discusses tests on the heating value of different coals in B.t.u., referring also to other considerations which affect the value of coal.

The Goldschmidt Thermit Company of New York City have under construction a new machine shop and foundry. The building occupies a site 34 ft. x 90 ft. in size, just back of their present factory in Jersey City, and is to be fitted up for the purpose of handling to better advantage the extensive repair work which is now being carried on at these works. Traveling cranes will be provided, and no expense will be spared to make the building the most complete thermit repair shop in the country. Special attention will be paid to the rapid execution of the repair of electric-motor cases, truck frames, cast-steel gear wheels, crank shafts, and, in fact, any wrought-iron and steel sections not exceeding 2000 lb. in weight.

The Schutte & Koerting Company of Philadelphia, Pa., manufacturers of steam and engineering specialties for power plant, chemical and other industries, have opened a branch sales office in the Keenan Building, Pittsburg, Pa., where they are represented by Mr. E. A. Knowlton. We also have received their new catalogs, which are being distributed in three sections; one section pertaining to apparatus for the chemical industry; one to apparatus for use in power plants, etc., and a general catalog illustrative and descriptive of their entire line of products, which is probably one of the most up-to-date and complete catalogs published by any engineering firm. These catalogs will be sent on request to those interested.

Nitrating Centrifugal.—We have received from Mr. J. W. Sittig, 5 Beekman Street, New York City, a descriptive circular of the nitrating centrifugal of Selwig & Lange, of Brunswick, Germany, whom Mr. Sittig represents in this country. While the Selwig & Lange nitrating centrifugal has stood the test of thirteen years' experience on a commercial scale in a very satisfactory manner, it has recently been considerably improved in various details, especially in the contrivance for circulating the acid during nitration, in the provision of a detachable steel acid receptacle, and in the Wolffshohl arrangement for the automatic immersing of the material to be nitrated. This centrifugal, in combination with the hydraulic gun-cotton conveyor, is used in numerous gun-cotton, explosive, celluloid and artificial silk factories and in many chemical plants. Nine such

centrifugals are in use in the Marine Powder Factory of the Navy Department of this country. In the circular sent to us the main principles of the apparatus and the features of recent improvements of the same are described and illustrated.

Metallic Manganese.—We have received from Messrs. C. E. Leavitt & Co., of New York City, a sample bar of metallic manganese, analyzing over 99 per cent pure. This metal has a specific gravity of 1.74, and is used to a considerable extent as a deoxidizer in brass foundry work, and also, to a limited extent, as a deoxidizer in making steel castings, being a substitute for aluminium. Tables recently published give the atomic weight of magnesium as 23.94, the atomic volume as 13.8, and the melting point as 649°.

Production and Consumption of Spelter.—According to an advance statement of the United States Geological Survey the production of spelter in the United States in 1907 was 249,860 tons (of 2,000 lb.), against 224,770 in 1906, the increase being 25,090 tons or 11.2 per cent. The consumption of spelter in the United States in 1907 was 228,509 tons, against 221,781 in 1906; the increase being 6,728 tons or 3.0 per cent. The production of spelter in the world in 1907 was 813,843 tons, against 775,871 tons in 1906, the increase being 37,771 tons or 4.9 per cent. This shows that almost exactly two-thirds of the total increase in spelter production in the world was obtained in this country.

Nitric Acid from Air.—The *Elektrotechnische Zeitschrift* states that Messrs. Sager and Woerner, in Munich, have applied for the right to erect a large nitric acid plant in Kardaun, near Bozen, in southern Tyrol. Water power is to be used and the power plant is to be equipped with six turbines each of 8,500 h.p. There is already a plant in Tyrol making nitric acid from air. It is located near Innsbruck and is furnished with energy from the Sill works. Nothing is stated concerning the process to be used in the new plant.

Digest of Electrochemical U. S. Patents.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

ELECTRIC FURNACES (Continued).

531,143, December 18, 1894, J. W. Woodfolk and J. C. Wharton, Nashville, Tenn.

Arc type. Springs an arc from a stream of acidified water to an electrode which may be a bar of iron to be heated or a tube containing a charge of ore to be smelted. Shows three furnaces: In the first, the arc is sprung from an annular sheet or film of water, flowing down the inside of a tubular positive electrode lined with lead, to a concentric bar of metal to be heated or melted, constituting the negative electrode. The sheet of water may be maintained in position by centrifugal force. The second furnace has a hollow globular body, serving as anode. A sheet of acidulated water flows down its inner surface, from an upper reservoir to a lower receptacle, being returned by a pump and pipe. The arc is sprung from the water to a tubular central cathode, containing, e. g., ore, fuel and flux. The resulting metal and slag collect in a lower crucible or separator, from which they are separately tapped. The electrolytic hydrogen from the water assists in reducing the ore, or may be burned by injected air. The third furnace is similar to the second, but the hollow anode has an oxidizable lining of carbon, lead or iron to combine with the electrolytic oxygen. Finely-divided oxidizable material may also be diffused through the stream of water. The tubular cathode has a cover which is connected to an exhaust fan by a valved pipe. The valve may be closed, to confine the vapors, which are then condensed by the water; or it may be opened and the vapors exhausted, and combustible gases and air drawn or forced through the charge, as a flame.

537,005, April 9, 1895, G. D. Burton, Boston, Mass.

Arc type. The arc is sprung from a stream of water containing dissolved chemicals, to lumps of ore to be smelted. The solution, which may consist of water, eight quarts, sodium carbonate, twelve pounds, and borax, one pound; or of water and equal parts of cream of tartar and sodium chloride, is dipped up from a receptacle by a conductive bucket-wheel, serving as anode, and poured upon the upper end of an inclined railway of lead, from which it runs onto an inclined hearth of wood covered with firebrick. Midway the hearth is a transverse metal plate serving as cathode and receiving the lumps of ore. This plate may be of lead, copper or iron. The stream of solution running from the lower end of the hearth is broken by a screen and deflector. The ore to be smelted may be a sulphite carrying gold, silver, lead and arsenic. A current of from one to three hundred amperes, at five to ten hundred volts, may be used. The ore may be fluxed and the lead, silver and gold successively smelted out, after burning off the sulphur and arsenic. The fused metal runs off the hearth and collects in the solution-reservoir in globules. The electrolytic hydrogen from the solution burns and assists in heating, a flame appearing over the cathode. Aluminium may also be smelted out of clay.

537,009, April 9, 1895, G. D. Burton and E. E. Angell, of Boston and Somerville, Mass.

Resistance type. Closed forge for heating metal bars or ingots. The bars are placed through holes in one horizontal copper bar electrode into aligned sockets in a parallel electrode, and constitute resistors. The forge has a bottom and sides of asbestos-board, and a dome top of mica or glass. The electric mains are cooled by an air current, extending transversely through a pipe leading from a blower. The forge may have a brick hearth. A modified forge consists of a tube of metal or a transparent non-conductor, having end electrodes to receive a single bar.

538,271, April 30, 1895, H. G. O'Neill, Boston, Mass.

Resistance type. A covered crucible to be heated is imbedded in a resistor of lampblack mixed with diatomaceous earth, which is contained in a vessel molded from a mixture of diatomaceous earth and kaolin or fireclay, or from asbestos. This vessel has two vertical opposite recesses in its sides, receiving carbon bar electrodes. It is also wound with a resistance wire, having sections connected to switch-points. The current passes in series through the wire and resistor. The heat generated may vaporize carbon.

The reduction of the most refractory ores may be effected in a small way by twelve hundred watts.

550,866, December 3, 1895, F. Chaplet, Laval, France.

Arc type. Substances to be melted are placed in an inclined retort-tube, e. g. of carbon, which is heated by one or more external arcs; or they may be placed in small crucibles introduced into the retort-tube. The tube may extend transversely through a heating chamber, being closed at its ends by stoppers, or it may terminate at its lower end within the furnace, and may have a top hole for delivering the melted substance into a lower receptacle. Two tubes may incline downward and meet within the furnace. The carbonarcing electrodes may be supported on wheeled carriages. An arc may be sprung near the tap-hole.

The furnace chamber receiving the retort tube or tubes has a concave roof and hearth, to reflect the heat from the arcs onto the tube.

551,014, December 10, 1895, J. A. Vincent, Philadelphia, Pa.

Arc type. The ore or pulverized charge is fed from a hopper-mouth through a horizontal passage between superposed carbon-block electrodes, by a screw. The upper electrode is automatically adjusted. The solid products fall into a pit and the gases escape to a stack. Suitable for production of calcium carbide.

NEW BOOKS.

THE METALLURGY OF IRON. (Being one of a series of treatises on metallurgy; written by associates of the Royal School of Mines; ed. by Sir W. Roberts-Austen.) By T. Turner. 478 pages, illustrated. Bound in cloth. Price, \$1.25. Philadelphia: J. B. Lippincott & Co.

AUTOCOGENOUS WELDING OF METALS. Translated from reports of the National School of Arts and Trades of France. By L. Leon Bernier. 45 pages, illustrated. Bound in cloth. Price, \$1. New York: Boiler Maker.

THE ENERGY CHART FOR RECIPROCATING STEAM ENGINES. By Captain H. R. Sankey. 170 pages, illustrated. Bound in cloth. Price, \$3. New York: Spon & Chamberlain.

LEATHER INDUSTRIES LABORATORY BOOK OF ANALYTICAL AND EXPERIMENTAL METHODS. By H. Richardson Procter. Second edition, revised and enlarged. 475 pages, illustrated. Bound in cloth, price, \$7.50. New York: Spon & Chamberlain.

THE ART OF PAPER-MAKING. By Alexander Watt. (A practical handbook of the manufacture of paper from rags, esparto, straw and other fibrous materials, including the manufacture of pulp from wood fiber, with a description of the machinery and appliances used, to which are added details of processes for recovering soda from waste liquors.) Third edition. 272 pages, illustrated. Bound in cloth. Price, \$3. New York: D. Van Nostrand Co.

THE DISTRIBUTION OF GAS. By Walter Hole. 703 pages, illustrated. Bound in cloth. Price, \$5 net. New York: Spon & Chamberlain.

PRACTICAL INDUCTION COIL CONSTRUCTION. By J. Pike. 128 pages, illustrated. Price, 50 cents. New York: Spon & Chamberlain.

ENGINEER'S POCKET DICTIONARY OF TECHNICAL TERMS. By M. Looff. French-English. 80 pages. Bound in cloth. Price, 60 cents. New York: Spon & Chamberlain.

A GUIDE TO TECHNICAL WRITING. By T. A. Rickard. 127 pages. Bound in cloth. Price, \$1 net.

BOOK REVIEWS.

THE DATA OF GEOCHEMISTRY. By Frank Wigglesworth Clarke. (United States Geological Survey. Bulletin No. 330, Series E, Chemistry and Physics, 54.) 716 pages. Washington: Government Printing Office.

This handsome volume, issued by the U. S. Geological Survey, is a treatise of broadest interest.

"Upon the subject of geochemistry a vast literature exists, but it is widely scattered and portions of it are difficult of access. The general treatises, like the classical works of Bischof and of Roth, are not recent, and great masses of modern data are as yet uncorrelated. The American material alone is singularly rich, but most of it has been accumulated since Roth's treatise was published. The science of chemistry, moreover, has undergone great changes during the last twenty-five years, and many subjects now appear under new and generally unfamiliar aspects. To bring some of the data together, to formulate a few of the problems, and to present certain general conclusions in their modern form are the purposes of this memoir. It is not an exhaustive monograph upon geochemistry, but rather a critical summary of what is now known and a guide to the more important literature of the subject. If it does no more than to make existing data available to the reader, its preparation will be justified."

There are 27 chapters, dealing with the chemical elements, the atmosphere, lakes and rivers, the ocean, the waters of closed basins, mineral wells and springs, saline residues, volcanic gases and sublimates, the molten magna, rock-forming minerals, igneous rocks, the decomposition of rocks, sedimentary and detrital rocks, metamorphic rocks, metallic ores, the natural hydrocarbons, and coal.

Prof. Clarke's work should prove of great interest to chem-

ists, mining engineers, metallurgists, and geologists alike. The careful and critical summary of what has been done in geochemistry in the past is of practical value just now when a noteworthy beginning is being made to apply the principles and methods of modern physical chemistry to the big problems of "worlds in the making." To anybody interested in these problems, Prof. Clarke's work will be a valuable help in showing what has been done in the past. The references to existing literature are very full. There is a good index of 48 pages.

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INDUSTRIE DES METAUX SECONDAIRES ET DES TERRES RARES. By Paul Nicolardot. 448 pages, 37 illustrations. Bound in cloth. Price, 5 francs. (Retail price in New York, \$1.25.) Paris, France: Octave Doin.

This is a book that exposita a new and growing field of metallurgical endeavor. As is well known, metals and earths that were only of scientific value 10 years or so ago have by their special qualities been found of value in our modern complex industrial world. We need only mention cerium, thorium and zirconium, whose oxides are the base of the incandescent mantel and the Nernst lamp, tungsten, molybdenum, which have proved of so much value in special steels, and tantalum, as well as tungsten, which are used in new high-efficiency electric filament lamps so startling to the central station manager.

Paul Nicolardot, captain of the French Artillery, has done a useful work in giving this compilation of what is known about these expanding industrial products. Their deposits, geology, chemistry, metallurgy and uses are given with a commendable fulness in detail. While the investigator of such subjects will be forced to get most of this information first-hand, nevertheless this book is a useful finger-post to show the way.

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THE ELECTRIC FURNACE: Its Evolution, Theory and Practice. By Alfred Stansfield, D. Sc., Associate of the Royal School of Mines, Professor of Metallurgy in McGill University. 211 pages, 53 illustrations. Price, \$2. Toronto: The Canadian Engineer; New York: Hill Publishing Co.

Dr. Stansfield's book is undoubtedly the best book now available on the electric furnace and its application in the metallurgical industries. Moissan's classical work deals with the electric furnace as a laboratory apparatus and is restricted to the limited field of applications in which Moissan himself was particularly interested. It is significant that in Moissan's work the name of Héroult is not once mentioned. Wright's more recent book is of a popular character and gives descriptions of all sorts of laboratory and industrial furnace designs, practical and unpractical, indiscriminately thrown together.

It is in comparison with Wright's book that Dr. Stansfield's new treatise appears to best advantage, being a concise and able summary of the most reliable data available on electric furnace construction, with descriptions of the most important electric furnace processes. The compilation of the many data has been made with sound metallurgical judgment. The full references to original papers and articles are most valuable.

The title of Dr. Stansfield's book seems to be too broad and not fully justified by the contents. Yet it is the best book now available on the electric furnace in its broadest industrial aspects and we must be grateful to the author for having written it.

There are seven chapters: History of the electric furnace; description and classification of electric furnaces; efficiency of electric and other furnaces, and relative cost of electrical and fuel heat; electric furnace design, construction and operation (containing data on refractories for furnace lining, materials for resistors, etc.); production of iron and steel in the electric furnace (production of steel from scrap, pig iron and iron ore; production of pig iron from iron ore, carbon and fluxes; direct production of steel from iron ore); other uses of the electric furnace (ferro-alloys; graphite and carbides; zinc, silicon, quartz, alundum, nitric acid, phosphorus, carbon bisulphide, aluminium and sodium); future developments of the electric furnace. The book is concluded by a good index of 17 pages.